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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1899.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY

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PREFACE.

THE following pages contain an account of the more important results obtained by the staff of the Geological Survey during the year 1899 in the field, the museum, and the laboratory. As far as possible, the account of the work of each member of the staff appears as it has been reported by himself. In regard to the field-work, a preliminary statement is given to show the general distribution of the mapping in each of the three kingdoms. This is followed by a narrative of the work of the past year in the various geological formations, beginning with the oldest.

Among the more noteworthy of these researches the following may here be referred to:—The investigation of the igneous rocks of part of Argyllshire, and particularly the examination of the olivine-monzonites and other more or less basic rocks round the Beinn Bhuidhe granite; the detection in the island of Arran of what are probably Arenig rocks with volcanic intercalations, such as have been already observed at various places along the southern edge of the Highlands; the establishment of the eruptive nature of what were believed to be tuffs and agglomerates in the south-east of Ireland; the closer determination of the stratigraphy of the probably Silurian rocks of Cornwall; the application of the knowledge obtained during the revision of the North Staffordshire coal-field to the recognition of the stratigraphical position of the Coal-measures under the younger formations of the centre of England; the important discovery of Rhætic strata and fossils in the island of Arran; the petrographical researches among the volcanic rocks of the Exeter district and among the so-called "ashes," "greenstones," and "felstones" of the east and south of Ireland; and

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the detection of phosphatic nodules with traces of prob
structure in the Torridonian rocks—the earliest indic
organised existence yet met with in Britain.

Some of these results have important economic
The practical application of the work of the Survey
to be much sought after by public bodies and by th
generally. A brief reference to this branch of the
which a large amount of time and labour is devoted
officers of the staff, will be found in Part IV. of the
Summary.

Attention may likewise be called here to the Catal
Fossil Types and Figured Specimens, inserted as an Ap
This list is the first of a series which is in prepara
illustrate the contents of the Palæontological Galleries
Museum.

ARCH. GEIKIE,
Director-Gen

Geological Survey Office,
Jermyn Street, London,
15th May, 1900.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1899.

Several changes have taken place in the staff of the Geological Survey in the United Kingdom during the past year. Mr. H. H. Howell, who joined the service as far back as 1850, when Sir Henry De la Beche was Director-General, reached the age-limit of sixty-five years on 13th July, and then retired. His office of Director for Great Britain has not been filled up, pending a consideration of the future organisation and work of the Survey, but in the meantime Mr. H. B. Woodward, F.R.S., is provisionally entrusted with the duties of Acting-Director for England and Wales, and Mr. John Horne, F.R.S., with those of Acting-Director for Scotland.

Mr. F. J. Bennett, who entered the Survey in 1868, has had to resign his appointment in consequence of ill-health. The vacancy thus caused among the Assistant Geologists has been filled up by the appointment of Mr. E. E. L. Dixon, B.Sc., A.R.C.S.

In order to press forward the revision of the North-Staffordshire coal-field and the country around it, which is much required in the interests of the coal industry, Mr. Pocock was transferred last year from Scotland to take part in that work, and has been engaged continuously upon it since the spring.

I.—FIELD WORK.

The field-work in each of the three branches of the Survey has been continued along the same lines and in the same districts as were described in the *Summary of Progress* for 1898. A brief outline of its general distribution will first be given here, and the detailed results obtained will be more fully stated in subsequent pages (p. 6, *et seq.*).

England and Wales.—The revision of the coal-fields and of the counties where the superficial formations had not previously been mapped has been steadily prosecuted.

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Thus in the counties of Leicestershire, North Sta
Derbyshire, Cheshire, and Shropshire, considerable p
been made with the examination of the coal-fields, an
mapping of the surrounding tracts which come into
of the one-inch map that contain these coal-fields.
has been carried on under the general supervision of
STRANGWAYS, by MR. GEORGE BARROW, MR. W. GIBS
I. POCOCK, and MR. C. B. WEDD. An area of 199½ sq
has been mapped, with 1,341 miles of boundary-lin
789 represent the sub-divisions of the superficial forn
Drifts. The Survey of the North Staffordshire coal-fie
nearly completed. That of the Pottery coal-field is fin
the map is being prepared for the engraver. The Sur
Cheadle coal-field has also been finished, with the exc
few patches of obscure ground. The re-survey o
Leicestershire has likewise been extended into a tract
Drifts had not previously been mapped.

The revision of the southern counties and the ma
the first time of the superficial deposits of that wide r
been continued along the same lines that were sketc
last *Summary of Progress*. The additional duties
undertaken by MR. WOODWARD have rendered it exp
relieve him of some of the supervision of field-work
entrusted to him. Accordingly the mapping in D
Hampshire, and Middlesex has been placed under the
MR. CLEMENT REID, F.R.S. MR. CAMERON has conti
work in the Thames Valley. MR. DIXON, who entere
duties in July, was first trained in the Survey method
work by MR. REID, and since then has been engaged on t
Eocene, and Drifts of the County of Dorset. MR. REI
besides supervising the work of his colleagues, has cont
revision of the Hampshire Tertiary Basin and of the sur
tracts of Wilts and Dorset The total area surveye
and his colleagues amounts to 181½ square miles, with
of boundary-lines, of which 407 relate to the Drift.

In Oxfordshire, MR. J. H. BLAKE, from Oxford as a ce
surveyed an area of 48 square miles, with 192 miles of b
including 167 miles of Drift-lines.

In Cornwall and Devonshire the re-survey has been c
by MR. S. B. WILKINSON, MR. W. A. E. USSHER, and M
HILL. They have surveyed an area of 135½ square m
have traced 397 miles of boundary, whereof 152 miles b
the Drift. The work has been carried on westwards fr
mouth to the neighbourhood of Liskeard and Looe.
Falmouth the coast and creek sections have been stu
detail along an extent of 68 miles, and the sections al
railway to Truro, and eastwards towards St. Austell ha
examined in order that the stratigraphy of the district
more clearly understood. A large part of the Land's En
has now been surveyed. Both MR. WILKINSON and M
were occupied during part of the year in the survey of
areas in Scotland, on which they had been engaged pre

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their transference to Cornwall, and which it is desirable that they should themselves complete.

Mr. G. W. Lamplugh, having completed the mapping and the Memoir of the Isle of Man, was transferred to the south of England, where his intimate knowledge of the Lower Cretaceous rocks of Yorkshire and Lincolnshire can be made available in the revision of these formations in Sussex and Kent, and in the preparation of a monograph descriptive of the Lower Cretaceous rocks of England. He has accordingly begun the re-survey of Sussex, where he has mapped an area of 50½ square miles, with 197 miles of boundary, including 66 miles of Drift-lines. Much of his time in the early part of the year was occupied with his Memoir on the Isle of Man, which has now gone to the printer. He was engaged also in an examination of the cores obtained from the deep borings and shafts that have been made in the search for coal in the south-east of England Sussex

In the South Wales coal-field the re-survey has been carried on under the general supervision of Mr. Strahan, with the co-operation of Mr. R. H. Tiddeman, Mr. W. Gibson, and Mr. T. C. Cantrill. An area of 104 square miles has been mapped, with 577 miles of boundary-line (263 Drift). As Mr. Gibson, during the greater part of the year, was occupied in the re-survey of the North Staffordshire coal-field, his services were only given for a short time to the South Wales Coal-field in order to complete some colliery information. In future he will be engaged continuously in the re-survey of the Midland coal-districts. In South Wales the field-work has been carried on as far westwards as the neighbourhood of Swansea. The first memoir on the district, being the Geology of the country around Newport, in Monmouthshire, written by Mr. Strahan, has now been published.

In England and Wales the total area surveyed in 1899 has amounted to 719 square miles, and the number of miles of geological boundaries to 3,266, of which 1,844 belonged to the mapping of the superficial deposits. The ratio of area to boundary-lines is thus almost exactly similar to that of the previous year, every square mile of surface having involved, on the average, the tracing of about four miles and a half of boundary-lines.

Mr. Jukes-Browne has been occupied in revising the proofs, in slips and in pages, and in preparing the index, of the first volume of his Memoir on the Upper Cretaceous Rocks of England. He has, moreover, completed the MS. of the second volume dealing with the various divisions of the Chalk.

Mr. Whitaker, F.R.S., has been good enough to communicate records of nineteen wells and borings, representing 3,867 feet of strata.

A number of note-books containing records of pits and quarries and of well-sections, together with some MS. geological maps, which belonged to the late Sir Joseph Prestwich, have been presented by Lady Prestwich.

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SCOTLAND.—The amount of field-work in Scotland somewhat reduced owing to several causes, among wh chief are the loss of MR. POCOCK'S services by his transfe the English staff, the detention of MESSRS. PEACH and in the office until the end of June in connection with t pletion of a large Monograph on The Silurian Rocks of S and the removal of MR. HORNE in the autumn from the take charge of the office-work in Edinburgh. The mapp been continued in the same districts as were mentioned last *Summary of Progress*.

Aberdeenshire. In Aberdeenshire, MR. BARROW mapped 34 square mil 121 miles of boundary; and in the same county MR. CU HAM-CRAIG reports 49¼ square miles, with 268 miles of bo

Argyllshire. In Argyllshire, MR. SYMES surveyed 31 square mile 204 miles of boundary; in the island of Jura in that coun WILLIAMSON mapped 31 square miles, with 69 miles of bo and in Islay he traced 119 miles of new boundaries in previously surveyed. In the same county also MR. mapped 7½ square miles, with 14 miles of boundary, a KYNASTON 61¾ square miles, with 414 miles of boundary.

Arran. In the island of Arran, MR. GUNN surveyed 9½ square with 84 miles of boundary

Dumbartonshire. In the county of Dumbarton, MR. CRAIG traced 72 m new boundaries in ground mapped some years ago.

Invernessshire. In the county of Inverness, MR. HORNE in Strath Nairn 3¾ square miles, with 11 miles of boundary; in the west same county, south-east of Glenelg, MR. CLOUGH su 37½ square miles, with 416 miles of boundary. MR. W stationed in the Fort William district, completed an a 42½ square miles, with 137 miles of boundary, and MR. MAN, with Beauly as a centre, an area of 30 square mile 168½ miles of boundary. In the island of Skye, MR. H mapped 29¼ square miles with 540¼ miles of boundary, wards of 18 miles of boundary in every square mile survey

Perthshire. In Perthshire, MR. WILSON surveyed 15 square mile 20 miles of boundary, and MR. CUNNINGHAM-CRAIG 105½ miles of fresh boundaries in ground previously mapp

Ross-shire. In the county of Ross, with Kinlochewe and Dingw centres, MR. PEACH mapped 52¾ square miles and 267 m boundary; MR. HORNE in the west part of the Fannich surveyed 6¼ square miles with 36 miles of boundary MR. GUNN, in the mountainous part of the Braemor Fannich Forest, mapped 10½ square miles with 87 mi boundary. In the eastern part of the same county, fro station at Beauly, MR. HINXMAN surveyed 29 square miles 102¾ miles of boundary.

Stirlingshire. In the county of Stirling, MR. CUNNINGHAM-CRAIG 29½ miles of new boundary-lines along the border o Highlands.

The total area surveyed in Scotland during the year has 480½ square miles, and the total aggregate length of boun lines traced amounts to 3,285½ miles. Each square mile ma

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has thus involved on the average the tracing of 6·84 miles of boundary.

IRELAND.—The whole of the one-inch map of this country having been completed and published, the field-work of the small staff retained for the purpose consists in revising the sheets of the map, and bringing it abreast of the present state of our knowledge of the structure of the country. Many years have elapsed since the maps of the eastern and southern counties were completed, and much new light has been thrown on the rocks during the interval.

The first revision has consisted in a re-examination of all the Silurian tracts in Ireland, with the view of separating the Lower from the Upper division, and of bringing the petrography of the ground up to date. It has also included the tracing of the superficial deposits in certain counties which were mapped at the beginning of the history of the Survey, but in which, as in England at the same time, these deposits were neglected.

In Wicklow MR. NOLAN has continued the mapping of the Drifts and the peat. In the same county, as well as in Counties Dublin and Wexford, some interesting and important re-examinations of the igneous rocks have been made by MR. EGAN and MR. MCHENRY, assisted in the petrographical work by MR. SEYMOUR. In addition to this region, further attention was given to some of the ground to the north of Dublin, with the view of obtaining material for completing the petrographical determinations necessary to allow the revised edition of the maps to be prepared and published. Thus the tracts of igneous rocks in the districts of Slane and Balbriggan were examined by MESSRS. MCHENRY and SEYMOUR, while a careful study on the ground was made of the dykes along the coast of Co. Down by MESSRS. EGAN and SEYMOUR.

In Co. Waterford MR. KILROE has completed the task assigned to him of tracing the boundary between Lower and Upper Silurian rocks. He has necessarily been much occupied by the eruptive rocks which form so large and important a part of the geological structure of that part of Ireland, and he has been able to effect changes of consequence in the representation of them upon the maps.

In connection with the revision of the Silurian rocks, MR. CLARK has continued to search the strata for fossils with the view of furnishing palæontological evidence for the mapping. Last year he was engaged in the Counties Clare, Tipperary, Kilkenny, Wexford, and Waterford. Near the granite of Leinster the rocks proved unfossiliferous, but near New Ross and Duncannon fossils were found that pointed to a Lower Silurian age. The well-known fossiliferous localities of Waterford had already been fully examined, and collections of specimens from them have long been displayed in the Survey cases in the Dublin Museum of Science and Art.

In the following account of the chief scientific and economic

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results obtained by the Survey during the past year, t
geological formation of the British Isles will be
succession, beginning with the oldest.

PRE-CAMBRIAN.

Ross-shire.

The mapping of the displaced masses of Lewisian g
the crystalline rocks embraced in the "Moine series," w
described in last *Summary of Progress*, has been con
the counties of Ross and Inverness. The district arou
Fannich, westwards to Loch Maree, and eastwards beyo
Luichart and Garve, has been further investigated by
PEACH, HORNE and GUNN.

MR. PEACH, to whom was assigned the more west
easterly portions of the ground, has furnished the f
report of his field-work.

e From the station of Kinlochewe on Loch Maree he wo
some of the details of the complex folds into which the
r. gneiss, the basement beds of the Torridonian, and the C
formations are thrown in the mass of rock which over
"Glen Logan" thrust plane to the north of Kinlochewe.
being much puckered and folded, these strata are also t
by minor thrust-planes and faults, which add greatly to t
culty of unravelling their structure. Two small dykes of
phyre were mapped, which have been intruded since the
of the movement.

From the same centre Mr. PEACH also completed an
about twelve square miles, between Loch Rosque and th
Bran on the south, and the Leckie Burn which joins th
lochewe River on the north. The western part of this gr
a high table land, with an average height above sea-level
1,000 feet, but deeply trenched by valleys, while the easte
rises into the mountain mass of Fionn Bheinn, which att
height of over 3,000 feet, and forms a conspicuous landma

The rocks of the tableland consist chiefly of quartzose
litic Moine-schists many of which are of the typical mic
flaggy character so well developed in the original Moin
trict of Sutherland. Towards the east, however, they oc
more massive beds. They alternate in varying degrees
dark biotite-schist over the greater part of the tabl
Fionnbheinn, on the other hand, so far as it has yet been m
is almost entirely composed of muscovite-biotite-gneiss or s
together with subordinate bands and lenticles of qua
granulitic schist, and a few thin sill-like layers of garnetif
epidiorite or hornblende-schist. The line of junction o
more quartzose Moine-schists and biotite-schists with the
covite-biotite-gneiss has been traced across the ground
referred to. To the north it joins up with the line which

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drawn by MR. POCOCK, and was referred to in the *Summary* for last year.* The continuation of the same boundary has been traced by MR. HORNE and MR. GUNN far to the north along the western slopes of the Fannich Hills into the plain beyond. Kinloch and Fio Bheinn (Peach.)

The ground mapped last year by MR. PEACH has a length of about five miles from west to east across the strike of the beds. Throughout its extent the apparent dip of the strata is towards the east, at angles varying from 20° to 40°. This arrangement arises from their being thrown into a series of isoclinal folds. Many of the minor folds can be seen in dip section, while the existence of others of greater amplitude can be demonstrated by following the layers of biotite-schist round the ends of the folds, where the "pitch" allows, so that what might appear to be successive outcrops of different bands of biotite-schist have thus been proved to belong to one and the same band. Further, there is strong presumptive evidence that, notwithstanding that the dip of all the structures is towards the east, there is a generally descending order of succession of the strata in that direction. The apparent dip of the quartzose granulites beneath the muscovite-biotite-gneiss of Fionn Bheinn is due to their forming the western limb of a much-compressed and overthrown anticlinal fold of great width. In the mountain itself, no core of rock of the type of the Lewisian gneiss has been observed; but granulitic, hornblendic and biotitic gneisses, like those which have already been described from Sgurr Mhuillin and Loch Luichart,† and surrounded by Moine schists and muscovite-biotite-gneiss, crop out in the stream which drains the southern slopes of Meall an Thuim Bhain at the extreme eastern limit of the area surveyed last year.

From Dingwall as a centre MR. PEACH was able to reach the ground between Auchterneed and Loch Luichart and to continue the work well into the southern flanks of the Ben Wyvis mountains. The same groups of rock as were mapped in the previous year‡ were again met with—(*a*) a series of granulitic, hornblendic and biotitic gneisses, which, with dyke-like masses of peridotite, occur on the crests of some of the anticlines, and are presumably Lewisian; and (*b*) an overlying series made up of schists or gneisses of two types, the prevailing one being a granulitic quartzose schist with more or less mica (Moine-schist) and muscovite-biotite gneiss. Thin bands of garnetiferous epidiorite and hornblende-schist, that occur as sills both in the Moine-schist and the muscovite-gneiss, appear to have been intruded into the rocks prior to their foliation and certainly before their plication, since they follow the numerous folds into which these are thrown. In addition to the sills of hornblende-schist the only other foliated igneous rock associated with the schists is a sill-like mass of augen-gneiss or granite like that mentioned in the last *Summary*. This sill may possibly be Loch Luichar Garve. (Mr. P

* *Summary of Progress* for 1898, pp. 15–17.

† *Op. cit.*, p. 7.

‡ *Op. cit.*, pp. 7–11.

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Loch Luichart and Garve. (Mr. Peach.)

continuous with one of those crossed by the railway nea Luichart, though the actual connection between them, if i is masked in the intervening ground by drift. Its outc been traced from nearthe road between Loch Luichart and moillie north-eastwards under the Old Red Sandstone ou Ben a Bhric and Ben nan Cabag across the watershed towa outcrop mapped by Mr. Gunn, who has followed it into t known exposure at the bridge which crosses the Blackwat Inchbae. From its prominence, its mode of weathering, prolonged extent, it has supplied a vast number of b which have been dispersed far and wide over the basin Moray Firth, and afford excellent evidence of the mo of the ice which transported them.

One thin dyke of lamprophyre, nowhere more than broad, has been traced in an east and west direction for miles a little to the north of Loch Luichart. This is th unfoliated igneous rock met with. Although the date intrusion cannot be directly determined, it may be inferre the fact that a mica-trap of somewhat similar type was fo cut an outlier of the breccia of the Old Red Sandstone east of Loch Garve.* It is probable that the lamproph this district are of later date than the basement beds of t Red Sandstone.

Fannich Forest. (Mr. Horne.)

The mapping of the mountainous region of the Fannich of which some account was given in the last *Summa Progress*,† was again resumed by Messrs. Horne and the former working southward, the latter northwards to Loch Broom.

Mr. Horne reports that from his station at Cabuie west of Loch Fannich he surveyed ground along the sou slopes of Sgurr Breac and A'Chailleach (3,276 ft.), the w peaks of the Fannich group, westwards to near An G and southwards to the Cabuie river. This tract lies to the of the area mapped by Mr. Gunn, and to the north of mapped by Mr. Pocock during 1898. The crystalline s met with in it belong to the same well-defined groups, have been previously described, but of which a brief enume may be here repeated for the sake of clearness in the follo descriptions of the latest results of the field-work.

1. Acid gneiss, with basic lenticles and bands of hornblende-s epidiorite and garnetiferous hornblende-rock, resembling certain typ Lewisian gneiss.

2. Massive biotite-gneiss, highly garnetiferous in places with irr masses of garnetiferous hornblende-rock. (Meall an't Sithe and Dubh gneiss.)

3. Granulitic quartzose schist or gneiss — quartz-biotite-granuli Moine-schist. (Meall a' Chrasgaidh rock.)

4. Flaggy biotite schist with small garnets.

Group 1.—The members of Group 1 enter the area mappe Mr Horne in 1899, along the western slope of A'Chaill

* *Summary of Progress* for 1898, p. 11.

† *Op. cit.*, pp. 11–17.

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between the contour-lines of 2,250 and 2,750 feet, where the pink granulitic acid gneiss with folia and eyes of felspar, and bands of epidiorite and hornblende-schist form a well-marked belt, readily distinguished from the garnetiferous muscovite-biotite-gneiss (group 2) both above and below it. Here the acid gneisses and the associated basic masses have a gentle easterly dip at angles varying from 10° to 15°. Owing to so gentle an inclination the members of this group present a highly sinuous outcrop for about six miles in the mountainous tract lying to the north-west of Cabuie. Along this outcrop numerous stream-sections show the lithological characters of the rocks. Upon the crest of the dividing ridge (An Sguman) for nearly a mile the overlying garnetiferous muscovite-biotite-gneiss has been removed by denudation, and the acid gneiss with its basic bands is laid bare in gentle undulations; the more prominent basic bands being repeated in the successive folds on the crest. There can be little doubt that the more massive basic bands, which here consist of green hornblende and plagioclase felspar, are intrusive in the acid gneisses, for they seem to transgress its foliation planes. In addition to the larger basic masses, thin strips of hornblende-schist and small lenticles and knots of hornblende-rock in the acid gneiss recall familiar features in the Lewisian gneiss of the north-west Highlands. The acid gneiss associated with these basic masses is coarsely granulitic and highly quartzose, with folia and eyes of felspar, as well as some biotite and muscovite. Sometimes it is finely striped and granulitic, with marked linear foliation, approaching the quartzose granulites of the Moine type. This latter type is frequently developed along the line of junction with the coarse garnetiferous muscovite-biotite-gneiss (group 2).

Fannich Forest. (Mr. Ho

GROUP 2.—The characteristic muscovite-biotite-gneiss of this sub-division both overlies and underlies the belt of acid gneiss just described, in the tract to the north-west of Cabuie. Both outcrops are believed to be repetitions of the same band due to folding. The overlying mass is well exposed on the higher part of A' Chailleach, and two small outliers of the same material are visible on the crest of An Sguman, between the Cabuie river and Abhuinn Nid. The underlying outcrop has been traced from the western slope of A' Chailleach, where this rock is exposed between the contour-lines of 2,000 and 2,250 feet south-eastwards to the mouth of the Cabuie river and the shores of of Loch Fannich. Throughout this ground the rock varies considerably in character. The normal type consists of large plates of biotite and muscovite with garnets and quartzo-felspathic material in thin veins and knots, presenting the characters of a coarse biotite-gneiss. Sometimes along the same line of outcrop the pegmatites disappear, the plates of mica become smaller, and the rock merges into a schist in which biotite and muscovite are the chief constituents, or a fine-grained mica-schist. Occasionally irregular masses of garnet-hornblende-rock appear in the garnetiferous gneiss, as for instance near the base

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Fannich Forest. (Mr. Horne.)

of the more easterly outlier on An Sguman, and outcrop underlying the belt of acid gneiss.

GROUP 3.—The flaggy granulitic quartz-schists, which distinguishing feature of this group, appear on the co west of A' Chailleach where they rise from underne garnetiferous gneiss (group 2), and dip to the east angle of 10°. The boundary line between these two g there well defined, and it has been traced south-eastward the south slope of An Sguman to a point on the Cabu about a mile west from Loch Fannich, where it enters the mapped in 1898 by MR. POCOCK. It was last year follo MR. PEACH along the west slope of Fionn Bheinn Achnasheen.

GROUP 4.—Not far below the junction line of the quartz with the garnetiferous muscovite-biotite-gneiss, on the west slope of An Sguman, a band of flaggy biotite- with small garnets appears, with a similar gentle dip to t These schists are likewise underlain by flaggy quartzose sc the Moine type. At present it is uncertain whether this corresponds to the biotite-schists of Sgurr Mor Fannich, t lithologically the rocks resemble each other. The result mapping of the Fannich mountains proves that the grou crystalline schists identified by MR. GUNN on the no slopes of that range are repeated on both limbs of a fold o amplitude, in which the various groups seem to preserv same relative position towards each other. It further a from the gentle inclination of the various groups in the w part of the area, at least, that the axial planes of the folds lie at comparatively low angles.

One instance of intrusive rocks later than the move which determined the foliation and plication of the schist found in the corrie at the head of Abhuinn Nid. It consi a thin dyke of lamprophyre.

Loch Fannich to Loch Broom. (Mr. Gunn.)

The ground surveyed last year by MR. GUNN lay nea watershed between Loch Fannich and Loch Broom. craggy, and difficult of access, it rises for the most part height of more than 1,500 feet, while three of the hills incl in it exceed 3,000 feet. The greater part of his mapping around Loch a' Bhraoin. The same four groups of rock w he had established in previous years, and which, as a stated, were followed by MR. HORNE on the southern side of watershed have been further traced by MR. GUNN on the n side. He furnishes the following notes of the developmen these rocks in the ground mapped by him last year.

The Biotite-schist of Sgurr Mor Fannich (No. 4) makes but a small portion of the area. In several places it appears be much more plicated than the quartz-schists which borde on either side. This difference may be due to the rock hav been of a softer nature, so that it yielded more readily to press than the hard siliceous rocks. In the streams to the north-w of the head of Loch a' Bhraoin, a fairly thick band of biotite-sc probably represents this rock or is a part of it. This ba

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Loch Fannich to Loch Broo (Mr. Gunn

however, has not yet been traced continuously over Creag Rainich, and connected with the biotite-schist near the Fain Inn. On the watershed to the south-west of A'Chailleach a band of biotite-schist, apparently much thinner than the last, which has been followed northwards into the streams that run into the head of Loch a' Bhraoin from the south, is not only much thinner than the Sgurr Mor rock appears to be, but also lies apparently on a much higher horizon, not far below the upper boundary of the Meall a' Chrasgaidh rock (No. 3). This band of biotite-schist has been followed by MR. HORNE for a long distance on the south side of the watershed. Its relation to the Sgurr Mor rock cannot yet be decided.

The band of flaggy quartz-schist of Meall a' Chrasgaidh (No. 3) presents a typical Moine-type, and occupies the upper part of the valley of the Strathbeg River which runs into Little Loch Broom. Its component members dip to the east-south-east and south-east, but near Creag Rainich, at the head of the valley, they curve round and run across the ridge to the south, while the inclination changes to a northerly direction along the north side of Loch a' Bhraoin, so that the band forms a synclinal fold, in the centre of which, and forming the highest ground, lies the garnetiferous gneiss (No. 2). Numerous sections of these flaggy quartz-schists may be seen in the small streams (which are far more numerous than would appear from the map) on the north side of Loch a' Bhraoin. The numerous streams on the south side of the loch, near its head, run for the most part in glacial drift and do not afford good sections of the rocks below. No intrusions of igneous material have been met with in the Meall a' Chrasgaidh rock, and it seems also to be almost entirely devoid of pegmatites.

The garnetiferous gneiss of Meall an't Sithe (No. 2) forms an outlier on the ridge north of Loch a' Bhraoin, extending for three miles, from Meall an't Sithe nearly to Creag Rainich. As just mentioned, it lies in the centre of a syncline, which is probably broken by a fault along its south-eastern side near the loch. The rock is often massive in appearance, and is largely made up of small bands of white or light-coloured pegmatites, which for the most part coincide with the foliation-planes. Irregular bosses and sills of a basic rock, for the most part hornblendic, are often met with. They are crowded with garnets, while large garnets are likewise distributed generally through the mass of the gneiss.

Near the northern edge of the mass, bands of a very acid schist or gneiss occur, quite different in character from the bulk of the rock. The largest and most important of these, seen about a mile west of the top of Meall an't Sithe, is almost certainly an infold of the siliceous rock (No. 3) below. Good sections occur in the crags all along this northern boundary, but perhaps the finest continuous exposure has been laid open in the crag on the south side of Loch a' Bhraoin from near the burn called Allt a' Goibhre, which issues from Toll an Lochain, round to Allt Brebaig. At the latter locality, the rock near its upper boundary

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is in places comparatively free from garnets, is more
foliated than usual; and contains abundance of white mi
very little biotite. A good exposure of the garnetiferous
visible in Allt na Goibhre, but to the westward the bo
between it and the siliceous flags is much obscured by dr
long distance, only small isolated sections occurring till,
west side of A'Chailleach, the rock again appears at the su

In Allt na Goibhre above the uppermost of two thick
of acid gneiss, the Meall an't Sithe garnetiferous gneiss, or
very similar to it, again comes out in great force. It o
the whole of the valley, spreads over the bounding rid
either side, and forms all the upper parts of A' Chaillea
Sgurr Breac with the high ground between them, thus occ
all the watershed for a distance of two miles. On thes
owing to the comparative absence of the small pegmatitic
the rock occasionally approaches more in character
ordinary biotite-schist.

Considerable additions were made last year to our kno
of the physical structure and composition of the acid
(No. 1) in the area mapped by MR. GUNN. The r
typically developed at the head of Allt Brebaig, between
Breac and Sgurr nan Clach Geala, where the coarse-g
grey acid gneiss has a marked north-west strike. In g
it is of a very acid type: some granulitic parts of it, i
might at first sight be confounded with the siliceous M
Chrasgaidh rock, were it not for the basic bands associated
the gneiss. A grey granulitic rock with marked linear foli
which occurs in the eastern branch of Allt Brebaig, 1,500
north-east of Sgurr Breac, has been found by MR. TEAL
microscopic examination, to be composed of quartz, felspar
two micas, with sphene as an accessory. Not far to the we
the burn, called Allt nan Eilig, a well-banded grey and c
coloured rock occurs, which MR. TEALL calls a fine-gr
granulitic schist. His description of its appearance unde
microscope is—No. 7509:—Epidote (grains and crysta
uniform dimensions in the different directions and occasio
containing brown cores, orthite?), pale green pyroxene, l
blende (scarce),water-clear felspar, and quartz, forming
irregular mosaic (individuals varying in size), sphene a
accessory: epidote pyroxene-granulite.

About a quarter of a mile farther up the same st
a specimen from one of a group of broad bands of b
coarse-grained, massive rocks of a basic character is desc
by MR. TEALL as a granitoid aggregate of green or gree
brown hornblende and plagioclase (oligoclase); sphene a
accessory. These basic bands appear to have all the chara
of true intrusive dykes and bear the same relation to
acid gneiss as the epidiorite dykes do to the normal Lewi
gneiss. They have been traced for about two miles
a north-west and south-east direction. Their total width va
between 100 and 200 yards, and in some places seems to co
wholly of dyke-material, while in others thin strips of acid gr

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divide the whole into distinct bands. A somewhat different type of basic rock is also met with in the same ground; lenticles of basic material—irregular lumps, and thin bands of hornblende-schist which apparently bear the same relation to the acid gneiss of the district as the earlier basic rock does to the Lewisian gneiss. Loch Fannich to Loch Broom. (Mr. Gunn.)

The rocks of this area are much plicated. A beautiful example of folding on a rather large scale occurs in the crags to the south-west of Sgurr nan Clach Geala. In ascending a stream three quarters of a mile south-south-west from the hill-top, we come upon a band of diorite about 30 yards broad, and 300 yards farther up, upon another band 70 yards wide, having a strip of gneiss 50 feet wide in the middle of it. The foliation of all the gneiss hereabouts dips uniformly and steeply towards east-north-east. As the broader band is traced northwards for about half a mile in the great precipice of Creag a' Fhuarain, the included strip of gneiss disappears and the whole then becomes one dyke, 100 yards or more in width. The smaller band widens out somewhat also as it is followed northward into the same crag, where the two bands are seen to form the two separate limbs of one isoclinal fold which curves round and spreads out over the crag. The foliation of the adjoining gneiss and the occasional foliation in the dyke itself show this clearly. In one part of the crag the width of the mass of diorite is as much as 800 feet. At the head of Coire Breac, so intense is the folding that the acid gneiss is felted with the garnetiferous gneiss, and both are shot with numerous pegmatites.

No basic igneous rocks have been noticed in the acid bands under A' Chailleach, but two acid bands seen in Allt na Goibhre contain dark basic material. In the uppermost of them some of the basic masses are foliated, and in one striking section the foliation of the acid gneiss cuts that of the included basic rock nearly at right angles—an almost exact parallel to the structure found in the Lewisian gneiss of the Gruinard district.

It is not necessary to allude further to the intrusive igneous rocks as they have been for the most part included in the foregoing account of rocks in which they occur. Those in the acid gneiss are generally diorites or hornblende-schists, while the bosses and sills of basic material associated with the garnetiferous gneiss are generally hornblendic in composition and crowded with garnets. The small pegmatites so generally diffused through the latter rock must generally be considered as segregations from the adjacent rock, and as the results of extreme metamorphism, but it is doubtful if some of the larger pegmatites have had the same origin. On the east side of Toll an Lochain and elsewhere masses of coarse pink and white pegmatite have a dyke-like character, several of them being many feet in breadth and stretching for a considerable distance. They generally run along the strike of the foliation, but some are seen to penetrate both the garnetiferous and acid gneisses. A specimen from Druim Ruadh is composed of large pinkish

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Loch Fannich to Loch Broom. (Mr Gunn.)

microcline felspar. Traces of a red lamprophyre found in two places at the northern end of Druim Ruadh, probably belong to a sill or dyke, similar in character to those previously described from this district. Rocks of this character, however, are not common: they have as yet been found in only three localities.

Although in the siliceous and granulitic Meall a' Chrasgaidh rock, no intrusions of igneous rock, and few or no pegmatites are met with, when the upper boundary of this band is crossed, they make their appearance both in the garnetiferous and acid gneisses. The coarsely crystalline character of the rocks and the abundance of pegmatites in them appear to be closely connected, and to result from the same cause—extreme metamorphic action—and only very slightly, if at all, from direct intrusion of igneous rocks. But the metamorphism, if, as is usually taken for granted, it was induced from below, can hardly be due to any alteration of the rocks in their present positions, for highly altered masses overlie others which are less altered. The garnetiferous and acid gneisses, for example, come above the Meall a' Chrasgaidh rock. The metamorphism would thus appear to have occurred when the acid gneiss and the garnetiferous gneiss were below the Meall a' Chrasgaidh rock, and in that case it will follow that notwithstanding the apparently regular order of succession now existing, the rocks are really inverted. Another possible explanation may be offered, viz., that the more highly altered rocks owe their present abnormal position to a lateral thrust, but no trace of anything of this kind has been noticed by MR. GUNN.

Inverness-shire.

District of Glenelg. (Mr. Clough.)

The examination of the ground between the Gleann Beag of Glenelg and Loch Hourn has been continued by MR. CLOUGH, who supplies the following notes of his work:—

Like the ground to the north, already described,* the tract surveyed last year, is composed in the main of rocks which seem to belong either to the Lewisian gneiss series or to the Moine-schists. Those believed to form part of the Lewisian gneiss series present very varied characters. They include a considerable proportion of hornblende-schist, hornblende-biotite-schist, eclogite, highly felspathic pink granulitic gneiss, and also some serpentinous and other rocks, which may be of igneous origin. Mixed intimately with these varieties are bands of limestone, kyanite-schist, graphitic calc-silicate seams, and other rocks probably of sedimentary origin. The limestone makes unusually broad outcrops on the south side of the Gleann Beag near Corrary and Balyraid. It is also well seen at other places. Various new localities for the spinels, which occur in the limestone,† have been noticed.

* *Summary of Progress* for 1897, p. 36.

† See *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 372. "On Spinel and Forsterite from the Glenelg Limestone." By C. T. Clough and W. Pollard.

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In the part of the Lewisian gneiss series between Rudha Mor and Rudha Buidhe a considerable proportion of pale acid gneiss which in hand-specimens greatly resembles some highly-altered felspathic grits, is so much mixed with hornblende-schist, in sill-like bands, lenticles and knots, and also with thin streaks and knots of pegmatitic material, that its true origin is difficult to determine. Some parts of it which can hardly be distinguished from the rest wind round the hornblende-schist lumps. There is likewise occasionally in these lumps a banded structure which ends rather sharply at their sides, as if the pale gneiss, or part of it, had once been in a state of flow since the formation of the banded structure. The intermixture of pegmatitic material is generally less on the coast between Eilean Chlamhuinn and Rudha Buidhe than it is further north-west, and at the same time the sedimentary aspect of the pale gneisses is greater. The pegmatite streaks between Rudha Mor and Rudha Caol, each rarely more than a few inches thick, are so numerous that they make up about half the bulk of considerable exposures of the rock. They consist chiefly of felspar, and often present a granulitic condition. In some parts of the district, particularly near the Moine-schist, between Eilean Mor and Ellanreoch and near Allt a' Ghearr Oir, broad bands of pink granulitic gneiss bear considerable resemblance to the thin granulitic pegmatites just referred to. **District of Glenelg. (Mr. Clough.)**

In most parts of the area in which the rocks occur that may belong to the Lewisian gneiss, the hornblende-schists and also the eclogites, take the form of sill-shaped sheets and lumps like small laccolites, rarely if ever showing clear evidence of intrusion. In some places, however, certain bands of hornblende-schist behave like dykes. Some of the rocks cut by these dykes are themselves also hornblende-schists, but of a more variable type, and generally coarser in grain than those of the dykes. The earlier hornblende-schists resemble in many respects certain members of the Lewisian gneiss which, when they were mapped in Sutherland were known in the Geological Survey by the name of "early basic rocks," while the later dykes of hornblende-schist more closely resemble foliated dykes of the well-known "Scourie" type. There are also one or two foliated dykes which consist chiefly of hornblende and biotite with little or no felspar. None of the dykes of hornblende-schist have yet been traced up to the edge of or into a Moine-schist outcrop, and therefore it is uncertain what their age may be in respect to the Moine-schist.

The most common rock in the Moine series is a granulitic siliceous schist. A more micaceous variety is mixed in thin parallel seams with the siliceous schist, and in some places forms the predominant rock in outcrops as much as 100 yards wide. Calcareous streaks and lenticles, an inch or two thick, are not uncommon. Thin streaks which contain a considerable proportion of magnetite may likewise be observed. As a rule the Moine rocks contain decidedly less epidote, whether in the form of strings or in small grains scattered through the matrix,

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District of Glenelg. (Mr. Clough.)

than the Lewisian gneiss rocks, but in a few places they include thin bands so rich in epidote grains as to acquire in consequence a pale yellow colour. Garnets usually abound in the more micaceous bands. One of these bands, extending between Eilean Mor and Rudha a' Chamais Bhain, is full in many places of thin plates of actinolite lying across the foliation and apparent bedding. Many of the more micaceous bands, for example, this band with the actinolites, and another about a mile south of Ellanreoch, occur next to rocks of the Lewisian gneiss type, but we cannot assert that they all do, and in many places the siliceous granulitic Moine schists are seen in direct contact with the gneiss rocks. It is noteworthy that up to the present time no kyanite has been observed in the micaceous schists which can with certainty be referred to the Moine series of this district, though the mineral is by no means rare in the Lewisian gneiss series.

The Moine rocks which occur in the west part of the area are almost free from pegmatitic material, while many of the Lewisian gneiss rocks of the same district, as already stated, largely consist of, or are permeated by, such material. This contrast, and the absence of bands of hornblende-schist, eclogite, &c., in the Moine rocks of the district, render it comparatively easy in most places to separate the two groups of rocks. In the more easterly districts the Moine rocks are often permeated through and through by pegmatites. The felspar of these pegmatites is not usually in a granulitic condition, but the quartz often is. In some places the pegmatites are as much as 10 or 20 yards wide; in others the pegmatitic material never appears in thick bands, but forms innumerable thin streaks and lenticles from about $\frac{1}{4}$ inch to 2 inches thick, and makes up perhaps half the mass of the rock. The Lewisian gneiss series, where it comes near these pegmatitic Moine rocks, also contains pegmatites of the same kind.

Both in the Lewisian gneiss and in the Moine rocks, occasional bands of biotite granite-gneiss cut the banding of the rocks in which they occur, and these granite-gneisses are also frequently "pegmatised." None of the bands yet observed exceeds 12 or 14 yards in breadth. Their foliation sometimes strikes against their margins and is in the same direction as the foliation in the rocks at their sides.

While the Moine rocks in the western part of the area contain no hornblende-schist, in the eastern part they not uncommonly include partially foliated hornblendic intrusions. Some of these intrusive bands are foliated parallel to their sides and cut both the banding and the foliation of the rocks in which they occur. They are more variable in composition, and generally coarser in grain, than the hornblende-schist dykes, already noticed, which may represent "Scourie dykes." They differ, too, from these inasmuch as they cut all the pegmatites with which they have been seen in contact. They are, therefore, probably of later date. Of three thin slices of these hornblendic intrusions which

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have been examined by MR. TEALL, he calls two biotite-amphibolite, and the third hornblende-biotite-schist. District of Glenelg. (Mr. Clough.)

As noticed in preceding years, the difference between the strike of the Moine rocks and that of the Lewisian gneiss rocks is rarely sufficiently great to admit of recognition in individual sections, but when exposures at a little distance from one another are compared, the Lewisian gneiss rocks which lie next the Moine rocks are often found at different places to present distinct types. At one locality, about one-third of a mile east-south-east of Rudha na h' Airde Beithe, there is also a distinct difference, amounting, perhaps, to about 12°, between the strikes of the two series of rocks. As the ground there is almost free from drift, in one section the Moine rocks are seen to be lying close to a certain band of hornblende-schist; but to the north-east a pink felspathic gneiss comes in between the Moine rock and the hornblende-schist, and gradually increases to a thickness of perhaps 40 or 50 feet. Still further in the same direction another band of hornblende-schist intervenes between the pink felspathic gneiss and the Moine-schists. These appearances, MR. CLOUGH believes, suggest either that the line between the Moine series and the Lewisian gneiss series here represents a thrust-line, or else that the former is younger than the latter and unconformable to it. Although good indications of stretching have been observed in all the rocks, no important thrust-line has been detected. During the different plications which have affected the district, the junction-line of the two series of rocks may, perhaps, have formed a line of special weakness, but this does not necessarily imply a visible displacement along it.

One of the most remarkable features in MR. CLOUGH'S field-work last year was the discovery of a band,—perhaps never more that 20 feet thick—which has a considerable resemblance to a highly-altered conglomerate or boulder-bed. Most of the larger fragments in it consist of a pink felspathic gneiss, like that which forms a great part of the Lewisian gneiss series in the neighbourhood. The examination of the band is not yet concluded and it would be premature to speak confidently of its character. It lies at the junction of the two great groups of rock near Rudha na h' Airde Beithe.

The prevalent folds in the district are isoclinal, and have limbs hading east or east-south-east, but with frequent twists in the strike into east and west, or north-west and south-east directions. Where the strike is east and west the limbs of the folds hade south. The long extension of the Lewisian gneiss rocks up Gleann Beag, past Balyraid, is owing to the east and west strike in that district. On either side of the gneiss area in this part of the glen extensive outcrops of Moine schist also strike east and west. These can be traced westwards until they twist and acquire a nearly north and south strike. Examples of rocks with north-west and south-east strike occur on the south-east side of Druim Fada, rather more than half a-mile north of the head of the Dubh Lochain of Arnisdale, and on Sgurr na Laire Brice.

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District of Glenegl. (Mr. Clough.)

Other folds also occur in which the limbs hade in opposite directions. These less acute examples appear often to twist the limbs of isoclinal folds, and consequently to be of later date. For instance, two sets of folds are seen together on the north side of Eilean Tioran, and on the side of the new road nearly half a mile east of Rarsaidh. The earlier folds in both these places are isoclinal with limbs dipping west-north-west or north-west, while the later folds have axial planes dipping gently east. It seems quite possible that the present hade of the limbs of the early isoclines in these localities may have been acquired during the later folding, and that their original hade was east or south-east, like the hade of the limbs of most of the isoclines in the district.

An important group of faults crosses the district in a south-west—north-east direction, from a little west of Eilean Rarsaidh to near Strathchomair. The Moine rocks of Ben Sgriol are thus brought against the Lewisian gneiss rocks on their north-west side for a distance of about a mile and a half. Near Loch na h'Oidhche, the Moine rocks of the eastern part of Beinn a' Chapuill on the north-west side of the faults, come near the Moine rocks of Ben Sgriol on the south-east side. The former are, as already stated, in an excessively altered condition, and thoroughly permeated by pegmatitic material, but the latter are less altered and contain fewer pegmatites. It seems probable, therefore, that the effect of the faults has been either to cause a considerable downthrow to the south-east, or else a large lateral shift which has moved the outcrop of the rocks on the south-east side of the faults, so that they now lie considerably to the north-east of the corresponding rocks on the north-west side.

Since the folding and the production of foliation many intrusions of eruptive material have taken place, chiefly in the form of dykes. The intruded material consists of (1) quartz-felsite, camptonite, mica-trap, or other variety of lamprophyre; (2) basalt, dolerite, and a rock allied to trachyte. About half a mile east of Rudha Mor a small oval boss of gabbro has also been observed. The dykes included in Group 1 have a general east and west or west-south-west and east-north-east direction.* In a considerable number of the lamprophyre dykes apatite crystals are large enough to form a feature in hand-specimens, some of the crystals being about $\frac{1}{4}$ inch long.

Beauly District. (Mr. Hinxman).

From his station at Beauly MR. HINXMAN has extended the mapping of the crystalline rocks through new areas of the counties of Inverness and Ross, lying between Strath Conan and Strath Glass. The greater part of the ground surveyed by him is occupied by the Highland schists, with their accompanying igneous intrusions, of which he has prepared the following notice :—

As in the regions already mapped to the south, the schistose rocks of the Beauly district can be separated into two chief

* It may be remarked that the general direction of the same class of dykes on the north side of the Glen More of Glenelg is west-north-west and east-south-east.

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groups:—(1) The Muscovite-biotite-gneiss; (2) the Moine schists; representing respectively an originally argillaceous and siliceous series. There is now little doubt as to the sedimentary origin of these rocks, in which the original bedding planes, or colour-bands indicating differences in sedimentation, can still often be traced; while in some of the finer-grained rocks lines suggestive of current-bedding can even be detected. Beauly District. (Mr. Hinxman.)

The Muscovite-Biotite-Gneiss varies in character from a tolerably fine-grained, flaggy, or schistose rock to a coarse, flakey gneiss with corrugated and crumpled folia. The coarser varieties contain much quartzo-felspathic material—possibly of segregative origin—disposed in eyes and strings along the planes of foliation. The rock is also characterized in many parts by large rounded flakes of muscovite lying at various angles to the bands of felted micas (the "spangle-schist" of Badenoch). Garnets are generally abundant, and often of large size. Considerable deposits of garnet sand are found in the streams flowing through areas where these rocks occur. Bands of kyanite-gneiss seen on the spur which runs east from Carn nam Pollan in the north-west corner of the Erchless Forest, lie near the edge of the main mass of muscovite-biotite-gneiss, and are met with also as narrow infolds with the Moine-schists a short distance from the eastern edge of that mass. The kyanite combines with quartz, garnet, and biotite, to form prism-shaped aggregations which project at different angles from the weathered surfaces. The kyanite is clearly a secondary mineral, and as there is apparently no mass of intrusive igneous rock at the surface in this locality, it is probable that the presence of this mineral is due to regional rather than to contact-metamorphism.

The Moine-schist group is composed of a series of fine-grained, thoroughly granulitic, schists and granulites. The relative amounts of quartz and mica (usually biotite) present in the rock continually varies, and the resulting gradation of one variety into another, makes it difficult to draw satisfactory boundary lines between the different types of rock in the field. An attempt, however, has been made to separate out the more siliceous bands—coloured as quartzite on the map—leaving a residuum of undifferentiated quartz-biotite-granulites, gneissose flagstones, and biotite-schists. These granulitic quartzites form lenticular masses with an irregular outline in the gneissose flagstones north-west of Struy, and are also largely developed about Scatwell in Strath Conan. On the summit and slopes of Beinn a Bh'ach Ard several lenticular bands of quartzite, infolded with the coarse muscovite-biotite-gneiss, differ somewhat from the ordinary type. They are highly siliceous, contain little or no mica or felspar, and weather with a snow-white crust. The structure of the rock is coarsely granular and highly crystalline, and very similar to that produced in the siliceous Moine-schists of N.E. Sutherland by igneous intrusions. The rock has the appearance of being in an advanced stage of thermo-metamorphism, and its present condition may possibly be referable to the same causes which have produced the

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Beauly District. (Mr. Hinxman.)

extreme metamorphism of the coarse garnetiferous muscovite-biotite-gneiss and the kyanitic bands which are found in its immediate neighbourhood. With regard to the structure of the ground over which these rocks have been recently mapped, it may be remarked that the schists of Strath Glass are arranged in a series of folds, whose long axes run in a N.N.E.-S.S.W. direction. The folding is almost invariably isoclinal, both limbs of the fold being inclined to the south of east. The quartz-granulites and flagstones that appear from beneath the old red conglomerate W. of Aigas are rapidly folded at high angles, and here, as in several other localities cleavage-planes passing through these minor folds can be detected. These rocks contain thin seams and bands of the muscovite-biotite-gneiss, which is brought in by a major fold at Craigdubh and extends in a line of irregularly lenticular masses northwards to Glen Goibhre. The gneissose flagstones again appear on the further side of this fold and alternate with numerous infolds of granulitic quartzite. These are followed by the main outcrop of the coarse muscovite-biotite-gneiss which crosses the river Farrar at Culligran Falls, and continues northward, forming the high mountain ridge of Beinn a' Bh'ach Ard. The western edge of this belt of gneiss has not yet been mapped, but there is good reason to suppose that it is succeeded by a series of highly siliceous rocks. In the Strath Conan and Glen Orrin district the long axes of the folds seem to be less regular in their disposition and the pitch more variable; so that the boundary-lines will, no doubt, prove to be more complicated than in the region just described.

The only fault of importance in this area is that which has determined the strong line of feature which runs N.N.E. from Erchless Castle along the course of the Allt Mhòr, and the deep hollow in which lies Lochan Fada and the stream at its head. The line of this fault is approximately parallel to the strike of the schists and does not produce any recognisable displacement; but at various points along its course, and especially in the upper part of the stream flowing into Lochan Fada, the rocks are much crushed and brecciated. Its course to the north of Urchany is concealed by peat and drift, but is possibly continued in the line of dislocation which crosses the River Orrin four miles further north, and throws down the Old Red Conglomerate against the schists at Muirton Falls.

The oldest intrusive rocks observed in the Beauly district appear to be a set of bands or sills of amphibolite and hornblende-schist, more or less lenticular in character, which occur on two horizons in the Moine-schists. Their trend is approximately parallel to the general strike of the schists, and the foliation-planes of the latter are continued into the amphibolite. These divisional planes are, however, constantly crossed by the edge of the basic rock, the marginal portion of which is invariably finer-grained and more schistose than the centre. The coarser bands are often highly garnetiferous, and show a tendency to *augen*-structure in the hornblende crystals. These bands may hence be regarded as

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representing masses of basic igneous material intruded into the Moine sediments before the development of their present schistose structure. The most easterly group of them is associated with the gneissose flagstones of Strath Glass. A second group has been mapped about Scatwell, in Strath Conan, among the quartzites and quartz-granulites of the siliceous zone. They appear to be more numerous here than in Strath Glass, but in both localities the repetition is probably in a large degree due to rapid folding. A particular sill can often be traced round the end of a fold, and it is possible that at each horizon the number of original intrusions may have been small. **Beauly District. (Mr. Hinxman.)**

The acid intrusions in Strath Glass take the form of veins or sills of granite, pegmatite, and felsite. These appear to be later than the movements, which produced schistosity in the Moine-schists, and, except in a very few instances, do not exhibit any parallel structure. The veins of granite and pegmatite are most abundant in the ground between Erchless Castle and Farley Wood, where they form a belt of parallel intrusions running east-north-east, and cutting obliquely across the strike of the schists and hornblende-sills. The smaller branch veins which they give out, often, however, follow the foliation planes of the schists as lines of least resistance. These intrusions, which often measure 20 or 30 yards in breadth, are coarsely crystalline and generally more or less pegmatitic in structure. They are composed of abundant oligoclase, alkali-felspar, quartz, and muscovite. Vermicular pegmatite has been detected under the microscope in a specimen taken from a vein north-north-east of Urchany. The veins here described show no foliation; but a single vein, similar to them in composition, but with marked flaser-structure, occurs at Creag Ard Bheag, 1¼ miles north of Erchless Castle. A sill of compact, very hard, brick-red felsite, with the same east-north-east trend, has been traced continuously for nearly 3 miles through the Moine-schists to the north of Struy.

A new point in the work of the past year has been the discovery of a considerable area of solid granite in Glen Orrin, about 4 miles west of Fairburn House. The appearance of numerous granite veins in the schists of Glen Orrin heralds the on-coming of the main mass, which forms an irregular area about a mile and a-half in extent, on the north side of the river. The rock is a medium-grained white or grey granite, wherein the mica, which is not abundant, is usually biotite, muscovite being also sometimes present in small quantity. Near the southern margin of the mass the amount of mica greatly decreases, and the normal granite appears to pass into a border of aplite. A typical specimen of the rock examined under the microscope by Mr. Teall, is described by him as composed of oligoclase, alkali-felspar, quartz, biotite, and muscovite (scarce). The alkali-felspar shows traces of microcline-structure, and vermicular pegmatite is present. Though there is sometimes a tendency towards a parallel arrangement or orientation of the flakes of mica, the rock cannot be said to be foliated.

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Beauly District. (Mr. Hinxman.)

The junction of the rock with the surrounding schists is, as is usual with the intrusive masses of the central Highlands, exceedingly complex and irregular. The granite is fringed with innumerable apophyses and detached veins traversing the schist, while fragments of the latter are thickly scattered as inclusions within and near the margin of the mass. Neither in the main body of the rock nor in its apophyses is there any appearance of a chilled edge, the rock in the smaller veins being as coarsely crystalline as in the interior of the mass. It may be further observed that the trend of the boundary of the granite, and of its fringing veins, as well as the disposition of the inclusions, has a marked tendency to conform to the strike of the surrounding schists. The inference may be deduced that the intrusion of the granite may not have been accompanied by any great disruption of the rocks, but that it rather took the form of a sill, which has made its way more or less along the planes of schistosity. The absence of any distinct foliation in the rock, even in its smallest apophyses, seems to differentiate the Glen Orrin Granite from the granites of East Sutherland, in which foliation of the margin and offshoots is a marked feature. Not improbably this mass may belong to the period of intrusion of the newer granites of Strathspey, to which it bears a considerable resemblance in character and composition.

A comparison of the Glen Orrin granite with the granite and pegmatite of Strathglass, above described, shows a striking resemblance in composition, and even in minute structure between the two rocks, the Strathglass pegmatites being slightly the more acid of the two. It seems therefore reasonable to assume that these veins of acid material may possibly be due to a later phase of the intrusion of the same magma.

DALRADIAN OR YOUNGER SCHISTS OF THE SCOTTISH HIGHLANDS.

For some years past the Geological Survey, while prosecuting the mapping simultaneously in the north-western counties and in the central, eastern, and southern Highlands, has refrained from any attempt to correlate the great series of schists of the region to the west of the line of the Great Glen with those to the east of that line. It has long been abundantly evident that in the north-eastern, central, and south-western Highlands the schists represent a great succession of truly sedimentary rocks. The age of these rocks and the date of their metamorphism remain still to be ascertained, though some progress towards the solution of these problems has already been made. But there can be no doubt that the phyllites, quartzites, grits, conglomerates, and limestones which extend from the shores of Elgin, Banff, and Aberdeen to those of Islay and Jura have had a sedimentary origin, and may yet find a definite place either among pre-Cambrian or post-Cambrian formations. The occurrence among them of igneous rocks which have shared in their metamor-

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phism, and of later eruptive masses which have not been touched by the alteration, has been recognised not to affect that fundamental conclusion, even though in some places granitisation and foliation have been carried so far that it may be difficult to decide where a line should be drawn between what was originally eruptive and what was originally sedimentary material.

To the west of the line of the Great Glen, however, another kind of problem arose for consideration. In Sutherland and Ross the rocks that were found to have been pushed by vast overthrusts above the highest visible Cambrian limestones presented structures of extreme complexity, and for a time little light was obtainable as to their true succession and probable origin. Even now, after some years of careful scrutiny, it cannot be said that we have advanced far towards the removal of the difficulties with which any attempted interpretation of the ground is at once confronted. But there is a general agreement among the various officers who have been engaged in the research that the crystalline schists east of the great thrust-plane that destroys the continuity of the Cambrian succession of strata, include slices of the old or Lewisian gneiss, which have been dragged up from the east, and have been thrust westward towards the great rampart of unmoved ground which extends from Cape Wrath to Applecross. Some of these slices are of vast size. One, of which only a portion has yet been mapped, in the south of Ross-shire, must far exceed fifty square miles in area, and must be several thousand feet in thickness. These moved masses have had new structures developed in them by the mechanical deformation to which they have been subjected, but the traces of their original characters as part of the Lewisian gneiss have not been wholly effaced.

Much more difficulty has been encountered in the endeavour to trace the structure and history of the vast mass of crystalline granulitic schists, which have been grouped under the general name of "Moine-schists." Probably various groups of rock have been crushed and metamorphosed to make up these schists. As the mapping has advanced southwards, evidence has increased that much of the Moine-schists consists of material that was laid down as sediment. Probably the Torridon sandstone was largely drawn upon in the process of the manufacture of these schists, and there may also have been Cambrian or even later sediments which underwent the same conversion into a foliated crystalline condition.

The recent progress of the Survey in the Central Highlands and in Eastern Ross-shire has shown that the peculiar granulitic structure and composition of the Moine-schists, with their traces of colour-banding and even false-bedding, and their intercalated bands of muscovite-biotite gneiss, are precisely reproduced among the rocks of the Central Highlands. The two types of quartzose-flagstones and banded muscovite-biotite gneisses recur under similar conditions in Sutherland and Ross and in Inverness and Perth. The one suggests that they were originally sandstones,

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grits, or arkoses, while the other may have been of a more complex and argillaceous composition.

How far this identity of petrographical character can be taken to imply geological synchronism may be matter for discussion. Without at present attempting to decide this question, we may, in the meanwhile, conveniently retain the provisional name "Dalradian" for the younger schists of the region east of the line of the Great Glen. If it shall be shown, as seems probable, that the Moine-schists of the north-west pass into and form part of the Dalradian series of the Central Highlands, a step will be gained towards the solution of the problem as to the age and origin of the schists of both regions. We know that the Moine-schists of the north-west have been pushed into their present positions, and probably have acquired their present crystalline characters since Cambrian time. The Survey has detected bands of what appear to be Arenig rocks wedged in among the schists and grits along the southern border of the Highlands. It thus seems possible that the plication and metamorphism of the Highland schists were not concluded until Lower Silurian time, and that these schists may have originally consisted partly of older Palæozoic as well as Pre-Cambrian sediments.

Aberdeenshire.

Bynack District, Deeside. (Mr. Barrow.)

The area surveyed last year by Mr. Barrow lay around the Bynack, near the western source of the Dee. The mapping of the basin of Deeside is now complete, with the exception of a few small and rather inaccessible patches. For convenience of description the Bynack district may be divided into two parts, separated by a great fault—a continuation of the Glen Tilt fault, which has now been proved to continue far into Aberdeenshire. Not only does this line of dislocation correspond for a great distance with a marked dissimilarity in composition of the rocks on either side of it, but to a considerable extent it also coincides with a line marking a rapid decrease in their metamorphism.

The area west of the fault is composed entirely of crystalline gneisses, varying in tint from rather dark grey to nearly white, the change in tint being mainly due to the varying amount of brown mica present. By far the greater part of the series is highly quartzose, and possesses a typical mode of weathering. In the streams these rocks form massive pavements, admirably shown in the bed of the Geldie above its junction with the Dee. On the hillsides, free from drift, they form long ribs or terrace-like lines. Both in their dominant grey tint and in their mode of weathering they are substantially identical with the grey Moine-schists or gneisses of the north-west Highlands. Some subordinate bands of highly micaceous gneiss associated with them are characterised by a softer mode of weathering than the angular forms of the rest of the rocks. These bands alone contain abundant white mica; in most of the others this mineral is con-

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spicuously absent. As in other similar areas, this absence of white mica is accompanied by a total absence of the lenticular or overthrust structure, so characteristic of nearly all the true schists in the southern Highlands that have resulted from the alteration of sedimentary rocks. The perfect parallelism of the bands of different coloured material in many specimens is no doubt original bedding. It strongly recalls the curious intensification of the bedding produced in many banded rocks by contact or thermometamorphism. The splitting faces are often coated with brown mica, which imparts a bronzy aspect to the rock. From the highly quartzose nature of these gneisses alumina-silicates are not common in them, although with a hand-lens minute garnets can often be made out, which possess the clear port-wine colour shown by the same mineral in the sillimanite-bearing rocks close to the Galloway granite. These little garnets are most abundant in a white rock in which the quartz-grains are embedded in a paste of white felspar. By the aid of this rock, which can be easily recognised, the great spread of gneisses is seen to result from the complicated folding and subsequent metamorphism of a comparatively thin group of strata. Bynack District, Deeside. (Mr. Barrow.)

The microscopic examination of the gneisses shows that some of them possess remarkable structures. In addition to the common granular structure, from which they are usually classed as granulites, they present two others. The one which can easily be made out with a hand-lens, and may be conveniently called quartz-bleb structure, has the quartz embedded in a matrix of felspar, which often extinguishes in fairly large sheets. The other can only be made out with the aid of a microscope, and may be termed "pseudo-igneous," for structurally some of the rocks of this type are identical with many granites. They contain abundant micro-pegmatite of the vermicular type, and are specially rich in alkali-felspar, mostly potash. It may be that the original presence of the potash-felspar gave rise to these structures so characteristic of rocks that have been in a state of actual fusion. The large proportion of potash may have enabled these rocks to attain a state at least approaching pasty fusion, while the other bands in which potash is not so abundantly present were unable to do so. In the Southern Highlands, rocks possessing such igneous structures have been met with at only one other locality among the lowest known rocks in Dee-side, where again the rock is rich in potash-felspar. A striking feature of the whole area west of the great fault is the singular uniformity of the metamorphism. The rocks about Loch Tilt are just as highly crystalline as those six miles off, close to the edge of the great mass of the Cairngorm granite.

Over the entire district pegmatite occurs in two forms, either as little sills, which are of local occurrence, or as little dykes which, while never absent over any large area, tend to form a perfect network in the districts where they are specially abundant. The sills have a pronounced white colour, and are composed of *augen* of white potash-felspar, surrounded by

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Bynack District, Deeside. (Mr. Barrow.)

quartz-felspar material. With the latter muscovite, and at times garnet, are abundantly associated, and the whole rock possesses an intensely "flaser" aspect, not a vestige of which is seen in the newer granites of this region. The small dykes have a very distinct aspect. They often possess an outer margin of coarsely crystalline felspar, within which is a finer and greyer material. The grey colour of this inner material is due to the presence of brown mica. White mica and garnet are also present, but this part of the dyke is of very variable composition. These rocks possess the intense hardness of the similar dykes of the Cairnshee magma so abundant in the Banchory area, and there can be little doubt that these pegmatites represent a portion of that intrusion. The field-work of previous years has shown that the Cairnshee magma reaches the surface along a belt of ground stretching from the coast at Aberdeen, where it is specially abundant, to a point some distance above Aboyne, and its occurrence in Upper Dee-side in a direct line with the belt already referred to, serves to confirm the conclusions arrived at in the case of the muscovite-biotite-gneiss of the area to the south. Here the pegmatites of the Cairnshee type continue in a gradually narrowing belt for at least 40 miles, though the granite itself never reaches the surface. These phenomena accord with those recorded from the study of the Brittany Granites, by DR. BARROIS, who has shown that there is a long and a short axis to a series of granite intrusions. Along the long axis the granite is met with repeatedly, and even when when it sinks beneath the surface its presence at no great depth is often shown by the alteration of the overlying rocks. In the direction of the short axis, the metamorphism steadily decreases as a rule, and further exposures of the granite are rarely met with. The older granites exactly reproduce these conditions in the great distances through which the granites make their presence evident by their pegmatites, and the extreme slowness with which the metamorphism decreases along these belts. In a direction at right angles to the longer axis the pegmatites usually disappear rather rapidly, and a steady decrease in metamorphism is well marked. Around the head of the western branches of the Dee the pegmatites are specially abundant along a belt stretching from a point a little west of Loch Tilt to the Chest of Dee, and running roughly parallel to the line of decreasing metamorphism. Where they disappear to the north and north-east is not yet exactly known, but to the east and south-east they rarely cross the stream flowing from the head of the Tilt to join the Dee at its junction with the Geldie. The line marking the limit of uprise of the pegmatites corresponds exactly with the line of rapid decrease to the east and south-east in the crystallisation of the schists, and thus while the highly crystalline character of these Moine-gneisses has not been induced by the newer granite, its connection with the pegmatites seems specially clear. That these pegmatites do not belong to that granite may be inferred from the fact that not only do they not increase in number towards the great intrusive

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mass, but on the contrary frequently decrease. as may be clearly seen from the sections in and about the bed of the Dee. The pegmatites are specially numerous near the Chest of Dee and for some distance further up the river. They then decrease in number, and are rare near the granite. The actual junction of the Moine-gneisses and the Cairngorm granite lies in the bed of the Dee, and the marginal phenomena of the granite can be clearly studied. The hard pegmatites, if present at all, are there represented by two minute veins in the whole section. Bynack District, Deeside. (Mr. Barrow.)

At the southern end of this section in the Dee the pegmatitic material that really does belong to the newer intrusions may be seen. It consists of a red friable material, of variable composition, but always rich in potash-felspar, together with quartz, garnet, and muscovite. Occasionally it is pale in colour and sometimes must be broken before it will disclose its true nature. In addition to its friability, it possesses the distinctive character that no large block is ever free from drusy cavities. On the margins of these cavities the rock is coarsely crystalline, and the minerals have some of their crystalline faces more or less well developed. It is in such cavities that the well-known "Cairngorms" occur. This drusy character, everywhere present, is seen in the veins in the granite about Loch Muick, on the margins of the Ballater mass, and on the border of the Cairngorm granite in the Invercauld Forest. In the last-named ground this material also occurs well away from the main mass of the granite, where, having no longer a high temperature environment, it consolidated in fine-grained garnet-bearing dykes. The composition of these rocks about the head of the Dee makes it evident they must be newer than the main mass of the Cairngorm granite. They frequently cut that rock. It is needless to state that the hard white pegmatites never occur within the granite. A remarkable feature of the Cairngorm mass in this district, as in others, is the fine grain of many of the intrusions within it. Indeed, when free from druses, they are mostly fine-grained. In this respect there is a remarkable contrast between the small acid intrusions in the granite and those in the diorite. Similar material, occurring even on the outer edges of the diorite, is invariably coarsely crystalline.

In the area east of the great fault above referred to, surveyed by MR. BARROW, the Moine-gneisses are abruptly truncated by the dislocation, and with one exception an entirely different set of rocks lies on the east side. The observer suddenly enters upon the domain of the well-known Highland quartzite and limestone. Between these two members of the series a lenticle of altered sedimentary rocks of very variable composition and thickness is observable. In some places, however, though rarely in Upper Deeside, the limestone lies in direct contact with the quartzite, as so often happens in the Ben-y-Glo area. The lithological variations of this intercalated lenticle forcibly remind us of those so frequent and conspicuous at the base of any of the limestones of the Yoredale

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Bynack District, Deeside. (Mr. Barrow.)

series. As in that Carboniferous succession, there may originally have been a shale, a sandy shale, or a sandstone at the base of the Highland limestone. The mapping has shown that, on the whole, the most common material was probably a dark shale containing a small band of dark, somewhat carbonaceous limestone a foot or so thick. The intense plication which this lenticle has undergone gives the deceptive impression at first of a thick mass of strata, but it has been known for some years that the dark shale was really a thin band. The repeated folding and reduplication of the little dark limestone enables this structure to be clearly determined, as the Moine-gneisses already noticed are shown by the incessant folding of the curious white garnet-bearing rock to have acquired their apparent thickness by intense plication.

The great fault that gives to Glen Tilt the aspect of a huge furrow driven by a gigantic plough is not an isolated line of fracture. It is simply the master-fault of a great series. This series of parallel faults is crossed by a set of minor dislocations, which can rarely be traced far, though so great is their number and so potent have been the effects of their production, that in special localities it is almost impossible to find a specimen of rock not more or less decomposed by shattering. The main lines of fracture are often taken by dyke-like intrusions of newer granite material which occasionally attain the breadth of nearly a mile. The intrusive material may be entirely unaffected by the fault, all movement having ceased before consolidation; it may show a foliated or flow structure due to final movement during consolidation; or it may be actually crushed by post-consolidation movement. The last phenomenon is rarer than might be supposed, and is always confined to the margins of the dyke or special thin bands within it. Microscopic sections prove that specimens showing flow-structure and others showing post-consolidation crush may be found within a foot of one another. Indeed, all three phases may be at times met with in the same dyke at different parts of its course. That these faults are in the main older than the granite in them is obvious; it is equally clear that they are post-metamorphic; for not only do they completely destroy the crystallisation of the unbroken rocks, but, in addition, they bring the broken and decomposed material into a specially favourable condition for being acted upon by the intrusions. From an examination of thin slides made from a decomposed garnet-schist along the side of one of these faults in and about which the newer igneous intrusions were specially abundant, it appears that a new, very fine criss-cross micaceous structure has been developed, closely resembling that produced by the action of the great whin-sill in the North of England. Though a purely contact-structure, it bears no resemblance to the coarsely crystalline structure of the "hornfels" of the district; which is both cut by these faults and contains numerous intrusions of similar material. The more the evidence afforded by these dykes is examined the more clear is it, in Mr. Barrow's opinion, that the metamorphism of the whole region took place

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before the uprise of the granite, any local small alteration that may occur being at the expense of this older crystallisation and of a very low type.

Balmoral District. (Mr. Barrow.)

After leaving the upper Dee-side district, MR. BARROW and MR. CUNNINGHAM-CRAIG made an effort to finish the field-work in the district about Balmoral. This, however, they were unable to do as the ground proved to be of a more complicated nature than had been anticipated. Instead of a simple mass of normal granitite, the intrusions of the age of the newer granite have proved extremely variable and complicated. They range from a distinctly basic diorite to a pale acid rock rich in potash-felspar. The latter occurs chiefly in small patches and veins on the margins of the diorite. At times the two rocks are sharply distinct; at others there is an insensible passage from one to the other.

Standing on any elevated point outside the main mass of the Lochnagar Granite, this intrusion is seen to rise abruptly from the lower ground generally supposed to be composed of metamorphic rocks. Detailed mapping has now shown that close to the foot of the rising ground lies a series of patches of diorite of all sizes, which no doubt indicates the top of a large mass, more or less continuous under ground. Where these break through the metamorphic rocks the diorite is often fine in grain. The conviction from the field-work grows that fineness or coarseness of texture in such cases is largely due to the proximity to, or depth below, the original top of the mass.

The cordierite-hornfels has proved to possess a greatly wider extension than was formerly supposed. Exceptionally large masses of it occur on the north side of the Dee, about Inver. The actual tracing out of this type of alteration shows that, while often found close to the granite, it also often occurs at a distance of at least three miles from any large mass of that rock, the highly aluminous rocks that intervene being intensely foliated sillimanite gneiss.

Braemar District. (Mr. Cunningham-Craig.)

The district of Braemar, in which MR. CUNNINGHAM-CRAIG has been engaged for several years, was revisited by him last year, and he spent rather more than three months there, partly in the western part of the Glen Ey Forest, partly further north among the Cairngorm Mountains, and partly in the Forest of Balmoral. But the necessity of completing some scattered outstanding areas in the southern Highlands required him to pass the early and the late part of the working season in the counties of Perth, Stirling, and Dumbarton. He has supplied the following notes regarding the chief results of his recent field-work in the Braemar district:—

While generally confirming the work of previous years, which has been described in former *Summaries of Progress*, MR. CUNNINGHAM-CRAIG, in the course of mapping the black schist, limestone, and quartzite to the west of Glen Ey, has obtained new evidence bearing on points of special interest in the geology of the district. Among these the question of the order of succession of

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Braemar District. (Mr. Cunningham-Craig.)

the rocks may be specially mentioned. In the *Summary* for 1897 (page 54), reference was made to indications of considerable local contemporaneous erosion and deposit between the limestone and the quartzite, and, though the order of succession was not definitely stated, attention was called to the fact that the bed of limestone nearest to the quartzite is occasionally absent, as indicated by the sections near the head of Glen Ey. The adjoining ground to the northward has now been surveyed, and the evidence, while fully bearing out what has already been stated, is much clearer and more definite. The band of limestone which appears nearest the quartzite is there, as in Glen Ey, a pure saccharoid marble, which is occasionally almost in actual contact with the marginal beds of the quartzite, while, where it is absent, the quartzite comes in contact with certain variable schists often observable between the saccharoid bed and the less pure or "ribbed" limestone beds. These schists are frequently associated or intercalated with the latter. In sections in Coire Bhourneasg the quartzite, with bands of the "Coire Neid beds," seems to transgress the bedding of the variable schists, which occasionally intervene between it and the limestone, and in one or two instances it may be seen striking obliquely at and transgressing the beds of the limestone. Further down Glen Connie the quartzite lies in contact with the black schist, the limestone not being present, though in Coire Bhourneasg it occurs in a thick folded mass between the two rocks. In the Allt an t'Sionnaich specimens of what may be described as a calcareous quartzite show the bedding and banding of the quartzite, but contain a considerable quantity of carbonate of lime; the rock may have been originally a calcareous sandstone, formed by the deposition of arenaceous material contemporaneously with the erosion of a limestone.

Observations of the "pitch" of the folding give confirmatory evidence. At the head of Coire Bhourneasg a folded mass of limestone is seen distinctly "pitching" under a belt of biotite-schist, and the latter in turn "pitches" beneath the rusty "Coire Neid beds," *i.e.*, the lower part of the quartzite, which distinctly surmounts them in this section. From these data it may be inferred that the order of succession in this district is as follows in descending order:—

1. Quartzite—Rusty and thin-bedded "Coire Neid beds" (not always present).
2. Local unconformability.
3. Variable schists (frequently absent).
4. Limestone.
5. Black schist.

The black schist, as typically developed in the district, must be distinguished from the fine biotite-schists which frequently appear above the limestone and often closely resemble the former rock. This distinction has been noted on the field-maps wherever possible, but as the limestone appears to be developed

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in lenticular beds and is occasionally absent, especially where the black schist attains its greatest development, confusion between the two horizons is liable to arise. Braemar District. (Mr. Cunningham-Craig.)

In this connection the fact may be recalled that the conglomeratic deposit discovered in Corriemulzie glen (*Summary of Progress* for 1897, page 53), and considered as possibly representing the "boulder bed," contains numerous subangular and rounded pebbles of the typical fine purple biotite-schist and other variegated schists which have been frequently observed between the "ribbed" limestone and the saccharoid marble band. The horizon of this conglomeratic deposit lies between the quartzite and limestone, and the bed, though never well exposed, occurs actually on the margin of the quartzite.

In the northern part of Glen Connie, and in the ground between that valley and the Dee, flaggy and granulitic biotite-gneisses form the country-rock, to the exclusion of all other deposits, with the exception of bands of quartzite, which become more frequent and more massive to the southward. In this district, and in the area of metamorphic rocks north of the Dee, surveyed during the past season, the folding is flattened, and shearing movements have been relatively severe. North of the Dee, in this series of granulitic gneisses, zones or belts, consisting wholly or in great part of quartzite, can be mapped out along the hillsides for considerable distances. No evidence of unconformability between the bands of quartzite and flaggy gneisses has been detected, and so far the evidence bears out the suggestion (*Summary* for 1898, page 24) that these rocks may be the equivalent of the granulitic gneisses and quartzite of the Banffshire series, though they differ considerably from them in lithological characters.

West of the entrance to Glen Ey a felted muscovite-biotite-schist, conspicuous on Creag a' Chait among the flaggy biotite-gneisses, resembles closely the felted schist with quartz and albite segregations, described in the *Summary* for 1897 (p. 53), as occasionally appearing between quartzite and limestone. The same rock may be seen in the Ey section, south of the Colonel's Bed, in contact with a much sheared greenish amphibole-schist, which may be a crushed epidiorite, but is more probably the impure edge of a calcareous band, sheared and affected by thermometamorphism.

The western margin of the diorite, which has now been mapped, follows the eastern side of Glen Derry, where it comes in contact with the granite, and is pierced by several minor intrusions and tongues of granitic and pegmatitic material. In the course of the season, 20 square miles of the Cairngorm granite were surveyed, but nothing of importance can be added to what has already been published (*Summary* for 1898, pp. 25 *et seq.*) with regard to that intrusion. Variations in the texture of the rock are frequent, but, as a rule, without any clearly defined boundaries. Thin quartz-reefs and crush-reefs are noticeable, especially on the high ground; zones in which these are common may be seen near the summit of Beinn Muich Dhui. The

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Braemar District. (Mr. Cunningham-Craig.)

crush-veins have probably originated during movements in the granite mass, after its upper part had consolidated. The latest phase of the residual material, which has crystallised in cavities and in fissure-veins, caused by the contraction of the solidifying mass of granite, may be described as a muscovite-pegmatite. It is sometimes very coarse, and shows frequent graphic intergrowths of quartz and orthoclase.

About 17 square miles of the Lochnagar granite mass have also been surveyed. The rock forming this intrusion, though generally similar to the Cairngorm rock, presents many minor points of difference. It is never so coarse in grain as the main mass of the northern intrusion, and never attains on weathering such a deep red colour. Biotite is in some cases more conspicuous in it, while the rock apparently contains more oligoclase, and is, in consequence, hardly so acid in character. The residual material in veins is, as a rule, less coarsely crystalline, and also less acid in composition than in the Cairngorn mass, biotite being frequently present.

In the area west of Glen Ey, large irregular intrusions of a remarkable porphyritic rock are exposed, which can be traced to the Perthshire border. The principal intrusion attains a length of three miles, with a breadth varying from one-third to two-thirds of a mile, while other masses of lesser area, together with small dykes and sills of similar material appear in burn-sections. The largest mass stretches from the ridge north-west of Allt-an-Odhar shieling, over the top of Cairn Creagach, and along the ridge between Glen Connie and Allt Sionnaich in a north-north-easterly direction to the hill-top west of Aucherrie, and is never observed at a lower level than 1,600 ft. At several points this intrusion has vertical or highly-inclined margins, but it spreads out in a sill-like mass over the hill-tops, and is capped in one instance by a cake of metamorphic rocks. A similar but smaller mass of rock occurs on the westward side of a tributary of the Connie, at a distance of 300 yards from the main intrusion, while the same rock appears on Geal Charn on the Perthshire boundary as an extension of masses mapped in Perthshire some years ago by MR. DAKYNS. The main mass evidently acts as a somewhat irregular sill, as is shown by its mode of occurrence and form, especially the V-shape of the margin in the Allt Sionnaich glen. The material of these intrusions presents several differences from the other igneous rocks of the area. The rock is essentially porphyritic, and usually consists of phenocrysts of plagioclase, quartz, and biotite in a matrix which varies from holocrystalline to cryptocrystalline.

MR. TEALL describes one of the coarser-grained specimens (8498) as containing "idiomorphic plagioclase (oligoclase-labradorite), orthoclase (scarce), quartz, biotite (more or less replaced by chlorite), and iron ores. The rock is intermediate between a granite and a porphyrite; but rather more allied to the former that the latter." Another specimen, taken from the heart of the mass, contains a little microcline, and interstitial micropegmatite. It is thus seen that these intrusions are more

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basic than the normal acid intrusions of the Braemar area, but resemble on the one hand the Glen Tromie porphyry described by Mr. HINXMAN, and on the other hand the Newbiggin dyke described by MR. BARROW. It is remarkable that, although in the centres of these intrusions the structure approaches that of a granite, the rock being holocrystalline throughout with no groundmass, in the marginal areas a groundmass is well developed, and frequently quite compact in appearance, while the phenocrysts maintain their normal size and appearance in it, with rather more distinctly idiomorphic outlines. Thus it is evident that the intrusion of these rocks has taken place when the surrounding rocks were at a comparatively low temperature and that the margins of the mass consolidated more quickly than the centre. The difference of texture is especially noticeable where the intrusions have a sill-like form, while where a vertical margin is observed, the effects of rapid cooling are not so conspicuous. Braemar District. (Mr. Cunningham-Craig.)

Small dykes and irregular intrusions of the more quickly cooled variety of the granitoid porphyrite are observed in the Allt Cristie Mor and Allt Cristie Beg to the northward of the main masses, and it is remarkable that in these instances the igneous rock only appears at a comparatively low level. It is not clear how far the larger masses have been intruded along previously existing fault-lines. One of the masses upon the Perthshire border (Geal Charn) may have been so intruded, and this is also probably true of an ill-defined mass of finer and more acid material (the normal quartz-porphyry of the Braemar area), which appears on the ridge north-west of Glen Connie; but the main intrusion does not appear to follow any line of dislocation. On the contrary, the igneous rock has been crushed and shattered by fault-movements in at least two localities, viz., on the south-east side of Glen Connie and in the lower part of the section in Allt Sionnaich. MR. TEALL describes a specimen (8501) from the former locality as "a crushed igneous rock. The original rock was probably similar to those described above (8498)." The quickly-cooled edge of part of the large intrusion is described as follows by MR. TEALL: "8502, Phenocrysts of plagioclase, corroded quartz, hornblende, and biotite, in a micro- or crypto-crystalline matrix. Carbonates, chlorite, and epidote as accessories. Quartz-porphyrite."

The more acid of the lamprophyre sills and dykes—fine-grained, dark-coloured rocks, containing phenocrysts of red plagioclase, and occasionally hornblende—are frequently found in the neighbourhood of the granitoid porphyrite intrusions, but no inference of a common origin can be adduced from this association. Included in the main mass, however, on the north side of Allt Sionnaich occurs a patch of basic diorite, of which MR. TEALL supplies the following description: "Brown hornblende, augite and altered plagioclase, with apatite and iron ores as original, and carbonates and chlorite (after augite) as secondary accessories; augite-diorite." This rock is probably of earlier date than the porphyrite.

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Braemar District. (Mr. Cunningham-Craig.)

The latest phase of these remarkable porphyritic intrusions is seen in fine quartz-porphyries which are very noticeable near the edge of the larger masses, and which radiate out from the margins. These resemble in all respects the quartz-porphyries of the Braemar area, having invariably a fine micro- or crypto-crystalline ground mass, containing idiomorphic phenocrysts of quartz and potash felspar. In some cases, where these late intrusions being small very quickly cooled, the rock is a fine felstone with a well-marked banding due to flow.

Taking the whole area into consideration, we have a belt of country characterised by the presence of intrusions of a composition intermediate between the lamprophyres and the acid granites and quartz-porphyries: in some cases the intrusion may have taken place along fault-lines, but the rocks have also been considerably affected since their consolidation by the north-east to south-west fault-movements. In the northern part of the district the igneous rock has not reached to such high levels on the present surface of the ground, as in the southern part. Lastly, the latest and most acid phase of the injected material is indistinguishable from the Braemar quartz-porphyries, while the larger masses of the intermediate rock appear to be of more recent date than the diorites and some of the lamprophyres. From these facts MR. CUNNINGHAM-CRAIG infers that he is dealing here with a phase of the newer granite magma, intruded at a locally intermediate stage in the differentiation, which has given rise to basic diorite and lamprophyres, highly acid granites and quartz-porphyries in contiguous areas. The intrusion has taken place while the surrounding rocks were at a comparatively low temperature, as evinced by the fine-grained chilled margins. The source of the igneous material may be looked for in an underlying magma, the existence of which has been previously suggested by the evidence in neighbouring areas. As the latest of the granitoid porphyrite intrusions have been shown to resemble closely the quartz-porphyries associated with the Auchindryne granite, it may be assumed that the latter intrusions are somewhat later in date than the granitoid porphyrites—an assumption borne out by the fact that the Auchindryne granite and its apophyses have been intruded since the north-east to south-west fault-movements, while the granitoid porphyrites have been more or less affected by these movements. The distinctly less acid composition of these remarkable intrusions also favours this suggestion.

Specially interesting evidence bearing on the question of thermometamorphism has been met with in the tract west of Glen Ey, from which the rocks can be traced continuously eastward into an area of greater metamorphism, while outcrops of black-schist, limestone, and other deposits capable of showing clearly the effects of alteration occupy a large part of the surface, and can be examined to great advantage both in burn- and hill-sections. Kyanite is commonly observed in the black-schist, and staurolite more rarely; but the crystals, which have been developed since all shearing movement ceased, are

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not so large and conspicuous as those seen in Corriemulzie Glen. The tremolite-rock and the garnetiferous sill of hornblende-schist are well seen, though the former is never so highly crystalline as in the metamorphic area east of Glen Ey. Braemar district. (Mr. Cunningham-Craig.)

But the most interesting feature is the entire absence of the production of hornfels, except at the contact with igneous intrusions; it is evident that in Glen Connie we are beyond the hornfels area, and have entered a belt of country in which the metamorphism has not attained to that relatively intense degree of alteration. The limestones appear very little affected, except where in contact with the granitoid porphyrite intrusions. The metamorphic effects of these intrusions are of greater interest. It has been pointed out that though these igneous masses attain to considerable dimensions, they have quickly cooled margins, so it cannot be expected that any very extreme type of metamorphism should be observed in the sedimentary rocks along the lines of contact. A certain amount of alteration, however, has undoubtedly taken place. Where the granitoid porphyrite comes in contact with impure limestone bands in Allt Sionnaich, the latter are converted into a compact banded hornfels. MR. TEALL describes a specimen (8503) as follows:—

"Compact banded hornfels.—The specimen contains a band of dark-purplish hornfels between bands of grey and pale green hornfels. The dark purplish hornfels owes its colour to the presence of minute scales of biotite. The other constituents are granules of pyroxene and a colourless mineral, the grains of which are too small for precise identification. They are probably either quartz or felspar. The grey bands are devoid of biotite but richer in pyroxene. They also contain grains of the colourless mineral and large individuals of a mineral belonging to the scapolite group (dipyre). The scapolites are crowded with inclusions of pyroxene in the form of minute grains. The grains in the scapolite are distributed in exactly the same manner as in the rest of the rock, so that the outlines of the crystals can only be distinguished in polarized light. Similar rocks have been described from the Pyrenees as 'cornéennes compactes" by Professor Lacroix. They are there regarded as Lias altered by contact with lherzolite."*

Purer bands of limestone, in Glen Connie, are found near the igneous rock as white saccharoid marble, with traces of calc-silicates, which have not been determined.

No contact between the true black schist and the porphyrite is exposed in this area, as the intrusions are for the most part confined to the neighbourhood of the limestone, but a thin fold of black schist seen in Allt Cristie Mor among minor intrusions of the granitoid porphyrite, has been converted into an andalusite-hornfels, which MR. TEALL describes as "(8506) Micaceous aggregates with cores of unaltered andalusite, quartz, and biotite. Andalusite-hornfels (altered)."

* Étude Minéralogique de la lherzolite des Pyrénées et de ses phenomènes de contact. *Nouvelles archives du Muséum d'Histoire Naturelle*, 3rd ser., pp. 209-302.

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Braemar district. (Mr. Cunningham-Craig.)

The "purple schist," so frequently seen associated with the banded limestones, is also much affected near the junction with the intrusive rocks. It is essentially a quartz-biotite rock, but by the development of minute plates of "contact" biotite, it has been converted into a hard biotite-hornfels, the bedding being completely obliterated. Two specimens of the rock from different localities are thus described by MR. TEALL: "(8504) Black compact rock showing junction with porphyrite. It is composed of numerous quartz-grains in a matrix containing small scales of biotite and minute opaque dusty particles (? carbonaceous). The rock has the structure of fine grit."

"(8505) Very fine grained, almost compact, purplish hornfels. Minute scales of biotite and some larger crystals of white mica in a colourless mosaic, largely, if not entirely composed of quartz. Biotite-hornfels." The zone of alteration round these porphyrite intrusions is narrow, and little trace of the alteration can be detected in hand-specimens taken at a distance of a hundred yards from the igneous rock; the specimens examined microscopically were all taken from within 100 feet of the porphyrite, some from the actual junction.

Perthshire and Stirlingshire.

District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham-Craig.)

In continuation of his previous survey in these counties for the completion of Sheet 38 of the one-inch map of Scotland, MR. CUNNINGHAM-CRAIG has mapped the "Green-beds" in the neighbourhood of Brig o' Tuirc, and from that ground south-westward in a zone reaching through Loch Katrine and Loch Chon into Rowardennan on the eastern shore of Loch Lomond. As stated in last *Summary of Progress*, the mapping of these epidotic grits, by affording a reliable horizon, has sufficed to explain the nature of the folding, and to make clear many points in the structure of the district, which could not previously have been detected.

North of Brig o' Tuirc in Glen nam Meann and Glen Finglas the "Green beds" are found in simple outcrops resting upon the coarse pebbly grits of Ben Ledi, and dipping beneath the massive grits and schists, which at a higher level contain the main intrusion of epidiorite. Nearer to the mouth of Glen Finglas, what might be described as "corrugated outliers" of the epidotic grits, are seen upon the hill-tops. In these outliers the folding is distinctly shown; the plication, though it may be described as isoclinal, is in no sense comparable to the deep isoclinal folding of the central Highlands, the limbs of the folds being nowhere of any depth. Thus, in these outliers, the actual folding has no appreciable effect upon the form of the outlier.

As these rocks are followed south-westward, they appear on the high ground of Beinn Aan in shallow synclinal folds which rapidly become deeper, till on the shores of Loch Katrine the rocks are "packed" into a vertical isocline. The folding in this part determines the form of each outcrop. It is observable,

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however, that the folds are, as a rule, shallow and undulating upon the hill-tops, while in the lower ground the "limbs" of the folds become longer, so that the pitch of the folding—*i.e.*, the actual dip of the folded beds---is often difficult to distinguish. This structure is again complicated by a cleavage observable in the fine-grained and more homogeneous beds, but which does not greatly affect the coarser grits. In the vertical limbs of folds, this cleavage coincides with the bedding, but where the folding is shallower, the bedding crosses the cleavage obliquely, and the former structure is frequently almost obliterated, so that a false appearance of isoclinal folding is given.

District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham Craig.)

Observations of the "pitch of the folding" have been made where possible, and from these it appears that the pitch undulates considerably; this has a marked effect upon the outcrops of the "Green beds" betwen Loch Katrine and Loch Lomond. The effects of the rolling "pitch" are especially well seen about Loch Chon, the axes of the folds sloping towards the loch from both north-east and south-west, so that four or five synclinal outcrops appear on the shores of the loch, while the folds pinch out towards the hill-tops, and an outlier on the watershed is sometimes the only representative of a particular outcrop.

The effect of the isoclinal folding is to repeat the outcrop of the "Green beds" seven times on the southern shore of Loch Katrine. The compound synclinal folds in which these outcrops lie may be regarded as the westward extension of the trough which has been mapped from Balquhidder and Strathyre. Each outcrop is essentially a folded syncline. On the south-east side, the great trough is flanked by an anticlinal axis of the coarse pebbly grits of Ben Ledi, packed together in a vertical isocline, that seems to have acted during the folding movement as a line of resistance, against which the folding of the less massive beds took place. The pebbly grits make their appearance here and there in minor anticlines between the outcrops of the "Green beds," and their occurrence in this manner is confirmatory evidence of the fact that in this area there is only one series of epidotic grits, which is continually repeated by folding. The small thickness of the rocks, relative to the area of ground which they cover, is also strikingly shown.

To the north-west of the trough containing the "Green beds," the folding becomes shallow and irregular, the beds being rather "puckered" than folded, and the metamorphism is of a different type. Shearing has had greater effect, and the gritty beds appear chiefly as micaceous schists, with less trace of their clastic origin. This may be partly due to an original difference in lithological character, the coarser grits attaining their maximum development to the south-east of the trough, and the sediment becoming finer in grain to the north-west. But the chief determining reason is, doubtless, the change in the character of the folding, which has led to a different degree of dynamic metamorphism. Where the folding is shallow and irregular, differential movement under horizontal stress may be expected to take place more easily, and the greater dynamic metamor-

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District between Brig o' Tuirc and Loch Lomond. (Mr. Cunningham Craig.)

phism would result in the total or partial obliteration of original structures. These phenomena hold good as far as the great trough can be followed. Tracing it into Stirlingshire, the trough is seen to be affected by faults, and to become shallower towards the south-west; the outcrops of "Green beds" become fewer in number, and the folding less regular and less deep, till, near Rowardennan, at a distance of about a mile from Loch Lomond, a fault cuts off the "Green beds" entirely, the upthrow being on the western side of the dislocation.

Dumbartonshire.

The portion of Dumbartonshire between Loch Lomond and Loch Long has been searched unsuccessfully for outliers of the "Green beds"; it seems that their horizon is never actually reached, the ground being occupied by rocks of a lower horizon folded into shallow and irregular undulations, and showing no trace of the great synclinal trough.

The Luss Slates.—Boundary lines for these deposits had not previously been mapped. In tracing the outcrops, it was found necessary to map in detail certain characteristic bands of grit. The grit of Meall Garbh in the Pass of Leny, and that which makes such a remarkable feature at Anie near the foot of Loch Lubnaig, have been found to afford admirable horizons for mapping. The data obtained by the detailed survey of these grit bands has made the structure of the district clear; numerous faults have been detected, and their effects have been shown, while the somewhat irregular arrangement of the rocky islands near Luss has been explained by the presence of roughly north and south faults concealed by the lake-basin, but the existence of which can be demonstrated.

The slate-bands have been quarried for roofing material at Luss for upwards of two hundred years, but the profitable beds have now been exhausted in the present quarries. Fresh openings in the neighbourhood have failed to find workable slate in sufficient quantity. MR. CUNNINGHAM-CRAIG'S examination of the ground soon disclosed the reason for this failure. He found that a north and south fault cuts off the workable slate, bringing against it a mass of fine and coarse cleaved grits with some softer slaty beds. The general similarity of these gritty beds to the true slates deceived the quarrymen, who continued working further into the mass of grits in the hope of winning workable slate.

The fault, which splits into several branches among the finer beds, has been traced for upwards of a mile. It shifts the outcrop of the slate-band—the same band that is being worked at Aberfoyle—a quarter of a mile to the southward. Veins of quartz and calcite with some chlorite are common in the neighbourhood of this fault and its branches, frequently rendering the slate unworkable.

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Inverness-shire.

In the district of Strath Nairn Mr. Horne continued the mapping of the schists, and found them divisible into two well-marked groups: (1) Flaggy, quartzose biotite-gneiss of the Moine type; and (2) Extremely coarse biotite-gneiss, with highly-contorted folia, containing quartzo-felspathic materials, arranged in parallel folia or lenticles. With the latter are associated bands of garnetiferous hornblende rock. Strath Nairn. (Mr. Horne.)

In the district which includes both sides of the southern end of the Great Glen, Mr. Grant Wilson continued the survey described in last *Summary*. He has now completed the mapping of Glen Loy. The schists which occupy the greater part of that valley are of the ordinary Moine-schist type or gneissose flagstones with quartose bands more or less felspathic and micaceous. The boundary of the diorite, part of which has been already described,* has now been traced all round. The mass, which is found to occupy an irregular area of about five square miles, appears to have been intruded more or less along the foliation-planes of the flagstones, for its eastern margin conforms closely to the changes in the direction of the foliation of these rocks. Half a mile to the west of Inverskavulin, on the banks of the Loy, where a good contact junction of this rock is seen, the granulitic flags next the diorite are much baked and shattered, while the igneous rock in close contact with them has a close-grained or chilled edge. A specimen from this place is thus described by Mr. Teall:— South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

"[8489.] Coarse-grained, massive rock. Under the microscope, plagioclase (Andesine-labradorite) biotite and garnet, with apatite and iron ores as accessories. A diorite-rock in which biotite takes the place of hornblende: garnetiferous biotite-diorite."

Few granite dykes† like these mentioned in last year's report seem to cut that portion of the diorite which lies to the north of the river Loy.

On the east side of the Great Glen, or Glen Albyn, the work of last year was continued by Mr. Grant Wilson up both sides of the Spean valley as far as Roy Bridge; round the western slopes of Ben Nevis to the limit of the driving road in Glen Nevis and the greater part of the Mamore Forest.

The most important section in this area is that laid open by the River Spean from the falls of Mucomir to the junction of the River Roy, the bed and the rocky ravine of the stream affording an almost continuous exposure of the zones of schist between the rivers Spean and Lochy described in last *Summary*.‡

(1.) Sericitic mica-schist. At the falls of Mucomir a crushed and contorted green schist, slightly calcareous in places, with a few quartzite bands, is cut by several small epidiorite-sills. In

* *Summary of Progress* for 1898, p. 42.

† *Op. cit.*, p. 43.

‡ *Op. cit.*, p. 44.

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South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

the road deviation at the Free Church Manse epidiorite-sills compose over two-thirds of the section, and to the east of the Manse, both in the river and in the railway-cutting, the green contorted schists are pierced by a large mass of gabbro, which in turn is cut by a porphyrite-dyke. On the railway below the cross-roads at Torr an Eas the rock, which is well exposed, consists mainly of dark grey and green schists with thin bands of quartzite, and a few small sills of foliated epidiorite constantly repeated by being thrown into folds. In the next railway cutting further east thin brown bands are interlaminated with green and grey schists, which appear to have been originally impure limestones.

(2.) The same narrow belt of black schist traced in 1898 by the Ben Nevis Distillery to Auchindaull, a distance of four miles, is not seen further to the north-east, and is not represented in the Spean section.

(3.) Below Coneachan dark grey flaggy micaceous schists with quartzite bands succeed the sericite-schists just described. They are isoclinally folded to east-south-east at an average angle of 50°, the same bands being frequently repeated. The epidiorite sills and dykes so characteristic of the sericite-schists still continue in this zone, though less abundantly. About 100 yards to the north of the High Bridge and in the railway-section, steel-grey flaggy schists are seen to include thin zoisite-schist partings a few inches thick. A specimen from one of these bands submitted to MR. TEALL is thus reported on by him :—

"[8559.] Hornblende and garnet in a white saccharoidal matrix. Under the microscope both hornblende and garnet are micro-poikilitic. The white matrix is a granulitic aggregate of quartz, felspar, and zoisite : hornblende-zoisite-granulite (garnetiferous)."

From this point to Spean Bridge the river section presents an alternating series of grey micaceous flags with flaky and quartzose bands. To the west of the railway viaduct the constant repetition of this series by folding on a large scale is well seen in the rocky gorge of the stream. The same group of rocks continues for a mile above Spean Bridge, either with their foliation planes on end or highly inclined to the east.

From Tirandrish for 600 yards up to the railway viaduct fine phyllites and flaky schists alternate with thin quartzose bands. Above the bridge a belt, 140 yards broad, of strong pink spotted and white quartzite with micaceous partings makes its appearance. Its relationship to the rocks on either side of it, though at present obscure, will in all probability be explained by the future mapping of the ground to the north. This quartzite is succeeded to the east first by soft grey phyllites with calcareous bands; next by a narrow belt of corrugated black schist with garnets, followed by a strip (75 yards broad) of blue crystalline limestone, with a few partings of black schist and phyllite.

To the east of this limestone, phyllites and black schist, identical in every respect with those on its west side, are repeated by numerous folds to within 280 yards of the Cour water when

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South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

solid grey and slaty limestone with actinolite extends for a breadth of 166 yards. This belt of limestone is succeeded by calcareous phyllites which can be traced to about 150 yards beyond the mouth of the Cour water.

The general strike of the foliation of the whole of this calcareous series is north-east and south-west, and the planes are either vertical or else inclined to the south-east at a high angle. The detailed mapping clearly proves that the same limestone band, with black schist on either side of it, is twice repeated, and that between these belts of limestone, and on their east and west sides, a series of similar grey phyllites and schist with calcareous bands, evidently indicates a repetition of the same zone. This calcareous series comprises the (4) limestone and (5) black schist zones, already described as extending from Lismore to Glen Nevis.*

The calcareous series is last seen at the foot of the Cour water: thence to the River Roy it is succeeded by silvery-grey phyllites and mica-schists, often garnetiferous. A specimen from Achnafraschoille, microscopically examined by MR. TEALL, is described by him is as follows:—

"[8560.] Both biotite and garnet are micro-poikilitic. The former occurs in large irregular plates, which are not arranged parallel with the schistosity. The matrix is composed of quartz and white mica with small grains and crystals of iron-ore—garnet-biotite-phyllite."

These schists, although lighter in colour, appear to be the representatives of the (2) dark-grey, flaggy mica-schists on the west side of the limestone and black schist. This identification is confirmed by the interlamination, both at Croft Ninner on the Spean and at Auchaderry on the Roy, of bands of zoisite-schist similar in every respect to those already described as occurring near the High Bridge. In close proximity to the zoisite-schist in the River Loy several belts of grey phyllite appear, which contain large feathery crystals of hornblende, occasionally seven inches long, and covered with crystals of a pale rose-pink garnet not yet determined.

A large number of broad dykes traverse the calcareous series in the Spean section. Some of these exceed 20 feet in width and all have fine-grained chilled edges. MR. TEALL has examined several of these, and finds that they belong to the lamprophyre group, and may be described as dioritic lamprophyres. On both sides of the Spean limestone, similar dykes cut the mica-schists of Glen Roy and Glen Spean, with a general trend of E. 30°—40° N. On the west side of Glen Nevis a similar group of dykes traverses the same series of strata (black schist and limestone) on Bidean Bad na h' Iolaire† to the south-east of Fort William.

In the burn section between Lochan Meall ant' Suidhe and the river Lochay the Ben Nevis granite is cut by a few aplite

* *Summary of Progress* for 1898, p. 45.

† *Op. cit.*, p. 48.

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South end of Great Glen and Glen Spean District. (Mr. J. S. Grant Wilson.)

and lamprophyre dykes. In Glen Nevis and around Poll Dubh the biotite-schist, which lies to the south of Ben Nevis, is intersected by numerous lamprophyre dykes. Further north the binary granite of Mullach Nan Coirean is cut by a series of similar dykes. Their direction is the same as that of those by the biotite-schist, and many were observed to have chilled edges. A specimen of one of them from the Choire Deirg is thus described by MR. TEALL :—

"[8488.] Under the microscope it shows prismatic hornblende in a matrix of plagioclase more or less lath-shaped.—Camptonite."

This granite area is also intersected by several coarser dykes, which in all probability are closely allied to the camptonites. A specimen of one of these from the falls at Poll Dubh, submitted to MR. TEALL, is thus described by him :—

"[8563.] Medium to fine-grained pinkish rock containing hornblende. Under the microscope hornblende, biotite (mostly altered to chlorite) in a matrix mainly composed of idiomorphic plagioclase ; a little interstitial quartz—Lamprophyre.

On the Moor of Rannoch, where a small tract has been mapped by MR. WILSON, between the head of the Tulla Water and the River Ghoir, a fine-grained biotite-granite has been found in place between Loch Laidon and the viaduct of the West Highland Railway. Traced to the south over the moor, this rock becomes more hornblendic and less micaceous till about half a mile from its edge it becomes a typical diorite. Several large lamprophyre dykes cut both the granite and diorite while the surrounding flagstones are intersected by diorite dykes.

Argyllshire.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

During the past year MR. HERBERT KYNASTON continued the mapping of the Dalradian schists in the neighbourhood of Dalmally and Inveraray. From Dalmally the work, begun some years ago by MR. J. B. HILL, was carried on up to the eastern margin of Sheet 45 (one inch), and the boundary lines of the different series were joined up with their corresponding lines along the western margin of Sheet 46. In a northerly direction the work was pushed forward to the high ground at the head of Glen Strae, whence it was carried on during July to the north-east corner of Sheet 45 from Clais-gobhair in the Black Mount deer-forest. To the south of Dalmally the mapping was continued from Inveraray during September and October in the area drained by Glen Shira. The following notes of his field-work have been furnished by MR. KYNASTON :—

The sediments mapped consist of part of the garnet-schists, the Ardrishaig series, or calc-sericites, and the black slates, limestones, grits, and quartzites of the Loch Awe series. On the east side of Glen Shira a considerable tract is occupied by the calc-sericite series, which towards Ben Bhuidhe are thrown into numerous small folds and plications with accompanying litho-

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logical changes. The beds become harder and stand out in bold crags and ridges, while on the main ridge of Ben Bhuidhe itself the rock has evidently been converted into a true hornfels. Two or three small patches of granite appear on the Ben Bhuidhe range, resembling the finer-grained type of Glen Fyne; but the visible exposures of granitic rock seem too small to have caused the amount of alteration observed in the surrounding sediments. Since, however, this alteration is of a local character, and identical with the contact-type of hornfels-alteration in other areas, it would appear to be due in great part to a larger extension beneath the surface of the Ben Bhuidhe granite. It is possible that a considerable mass of granite may exist here, only small portions of which have as yet been tapped.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

To the north of Glen Shira, in the neighbourhood of Ben Bhreac, Ben Bhoidheach, and Ben Bhalgairean, the calc-sericite group has a fairly uniform lithological character, consisting of hard, often intensely puckered, greenish and grey phyllites, in which occasionally calcareous and quartzose zones may be observed. These Ardrishaig schists have here a decidedly more metamorphosed appearance (of the regional type) than further west. This fact and all Mr. Kynaston's observations during the course of the mapping fully confirm Mr. Hill's view on the progressive metamorphism of these sediments.* From this area the Ardrishaig schists can be traced in a highly altered state to the west of Meall nan Tighearn, whence they curve round into Sheet 46 along the northern flanks of Ben Laoigh. Typical calc-sericites—greyish and greenish sericitic phyllites with numerous calcareous zones—are found at Ciochan Ben Laoigh, where they form a fine feature, and in the crags of Fireach na Moine.

To the east of the calc-sericites come the garnet-schists. As the latter are entered the calc-sericites become gradually less calcareous as well as more siliceous and highly micaceous, until they are succeeded by massive and flaggy quartzose mica-schists, thickly studded with garnets.

On the west side of Glen Shira the boundary-line between the calc-sericites and the Loch Awe series was followed in a general north-north-east direction as far as Bealach nan Cabrach, whence it turns westward and was traced to the shore of Loch Awe close to Inistrynich. The Loch Awe series between Glen Shira and Loch Awe maintains similar features to those described in former Reports. The black schists (belonging to this series) were again met with east of Dalmally and were followed as a comparatively narrow zone along the south side of Glen Lochy to the margin of Sheet 45. In this more altered area they have the appearance of black phyllites with micaceous partings and often with quartzose bands. They are also frequently garnetiferous.

To the north of the Strath of Orchy and Glen Lochy the black schists and limestones become restricted to insignificant zones until they gradually die out altogether, and a large area is then

* *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 470.

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District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

occupied by quartzose schists and quartzites. The evidence of increased regional metamorphism is here again striking and apparently comes in somewhat suddenly. In fact, a considerably greater degree of metamorphism is observed in tracing the rocks for four miles from Dalmally in a north-easterly direction than in the course of the succeeding ten miles along the same line. The increase in this direction after the first four or five miles is comparatively slight as far as observations have yet gone. Near the southern boundary of the quartzose series rocks which appear quite gritty, and in which the individual grains can be easily distinguished by the naked eye, may be frequently observed, but further to the north-east the gritty nature of the rocks becomes gradually obliterated, the schistose structure grows more and more marked, until a quartzose schist is reached, which is often flaggy and maintains a uniform character over a large area, and in which the original clastic structure is almost, if not completely, lost.

Well within the altered area highly micaceous schists, often with both black and white micas and frequently garnetiferous, are not uncommon. Thus, garnetiferous mica-schists are well developed in Glen Orchy at Catinnis Bridge, and they again form a strong band near Clais-gobhair in the Black Mount, and are well seen on the south-eastern slopes of Ben Sroine. Lithologically they often bear a strong resemblance to the garnet-schists below the Calc-sericite group about Ben Laoigh and in the Glen Fyne area, but here they occur well within the quartzite area and are succeeded both above and below by quartzites and quartzose schists. The following section, observed near Clais-gobhair, may help to illustrate the relations of these garnetiferous schists. In apparently ascending order the subdivisions are:—

(1.) The quartzites and quartzose schists, in the immediate neighbourhood of Clais-gobhair. Then, in a burn section of rather more than a mile in length,

(2.) A green hornblendic schist or gneiss, the nature of which is at present doubtful.

(3.) Dark grey biotite-gneiss,—the biotite often developed in elongated leaf-shaped patches, irregularly distributed on the foliation planes,—passing into a schist with two micas, often gneissose, and with some small pegmatite veins.

(4.) Garnetiferous mica-schist, with two micas, garnets numerous.

(5.) Pale grey flaggy quartzites,—a narrow zone.

(6.) Silvery grey mica-schists, with two micas, only occasionally with small garnets. These rocks become very quartzose, and show, also, eyes and bands of quartzose material, which does not apparently represent extravasated quartz, but rather puckered and drawn out bands of recrystallised coarse grit. These rocks are again well seen about the east end of Loch Dochart. Near the top of this zone fine quartzite bands become more frequent and pass into

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(7.) The series of flaggy quartzites and quartzose schists, which spread over a large area.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

The green hornblendic schist (2) is a peculiar rock, regarding the nature of which a definite opinion cannot at present be given. Parts of it recall the epidiorite sills, so numerous in the Loch Awe area, but it does not seem to behave like one of these in the field. It appears to consist of a complex containing hornblendic, epidotic, and pyroxenic gneisses, sometimes with sphene, while some portions are calcareous. Mr. Grant Wilson, who mapped a portion of this schist, compared it to the scapolite gneiss, though it does not contain scapolite. Both this rock and the succeeding biotite-gneiss frequently contain small pegmatite veins. The biotite-gneiss is seen under the microscope [slide No. 8618] to be fine-grained in texture, and to consist mainly of biotite and quartz, with a small proportion of felspar, and occasionally eyes of granular quartz and small garnets. The garnet-schist [8619] is considerably coarser, but intensely puckered and well foliated. It is very quartzose and contains both white and brown micas, the former being slightly in excess, and a certain amount of felspar. The garnets have been broken up and show but little of their original substance, being now mainly represented by chloritic alteration products, biotite flakes, and granular quartz.

Almost throughout the whole area of the quartzite series surveyed, from the Strath of Orchy to the Black Mount, small pegmatite veins are fairly common. On both sides of Glen Strae and in the tract between that glen and Glen Orchy they are numerous in the quartzose schists, especially noticeable in the neighbourhood of faults. They occur chiefly as small veins and strings of coarse red felspar, usually associated with quartz, along the joint planes and other lines of weakness in the schists. Some veins consist mainly of quartz. Besides these veins, isolated pockets and grains of felspathic material, already noticed by Mr. Hill,* are well seen on the west side of Glen Strae, grains and patches of red felspar frequently occurring to such an extent as to give the rocks as a whole a reddish appearance. This Mr. Hill has attributed to the presence of the Ben Cruachan Granite; that is to say, either the felspathic material has been derived from the granite, or it represents an original constituent of the quartz-schist recrystallised owing to direct contact-action. There can be no doubt that "granitisation" of this kind has taken place in many parts of the Highlands. In the region around Ben Cruachan, however, Mr Kynaston's work in the field and with the microscope has led him to doubt whether the evidence might not be better explained in another way. As a general rule, as far as his experience of the Cruachan granite has gone, secondary felspar, which can be shown to be due to the direct contact-action of the igneous mass, is only found in the immediate neighbourhood of the

* *Op. cit.*, pp. 485, 486.

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District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

actual contact, *i.e.*, in the inner zone of hornfels alteration and such secondary felspar will usually present a fresh appearance under the microscope. The fact of the quartzites having a reddish colour, due to the disseminated felspathic grains, cannot be taken as any guide to the origin of such felspar. The majority of these quartzites and quartzose schists, throughout the ground surveyed, are rich in original felspar grains. They were at first fine-grained quartz-felspar grits, and they have frequently been observed to assume a reddish colour, due presumably to the weathering of the contained felspar, at distances from the granite very much greater than Glen Strae, and especially in the neighbourhood of faults or lines of crush, where the rocks are much shattered and decomposed. On the other hand, grey quartzose schists, containing abundant clastic felspar, may often be observed close against the margin of the granite, without any accompanying change of colour. Again, isolated grains or crystals of felspar, similar to those seen on the west side of Glen Strae, may be observed, up to quarter of an inch in diameter, in the quartzose-schists of Ben Donachan, three miles and a-half from the nearest exposure of granite, while veins and pockets of red felspar, up to three or four inches in breadth, are common in Glen Orchy in the neighbourhood of Catinnis, more than five miles from the granite. These felspar grains have always a very turbid appearance under the microscope, and are usually corroded, and often broken, and they are not restricted, as we have seen, to the zone of hornfels around the granite, but may be found several miles away from it. It is not always easy to draw the line between veins, pockets, small patches, and apparently isolated grains of felspathic material. A similar reddish colour might easily prevail in both secondary and original felspar; but there is no doubt that the rocks here considered are highly felspathic quartz-schists, which contain a large proportion of unquestionably original felspar, and these schists are traversed by felspathic veins, and structures of a similar nature. These structures cannot be referred to direct contact-action, nor can they have been injected from the granite. According to MR. KYNASTON, they belong to the same set of phenomena as ordinary quartz-veins, which form a common feature in the district. Veins and pockets precisely similar to those in the quartzose schists are found in the granite itself, especially in the coarse Black Mount type. From these considerations, MR. KYNASTON would refer this vein felspar and the occurrence of secondary felspar of a similar nature, though not necessarily in the form of a true vein, not to the presence of the granite, but to the same causes which give rise to the normal quartz and pegmatite veins, so common in igneous rocks and highly metamorphic regions, such as we are dealing with. Isolated reddish grains he would regard as original clastic material. That these should have escaped obliteration from the forces which produced the schistosity of the rocks, is not, perhaps, so surprising in view of the resisting nature of the rock, and the fact that the porphyritic felspars of the epidiorite-sills are

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frequently well preserved even in an area of garnetiferous mica-schists.

District between Loch Fyne and the Black Mount. (Mr. Kynaston.)

The sills of epidiorites and hornblendic schist are already well known from previous Reports, and those mapped during the past year do not call for any special notice. It may be remarked, however, that as the mapping advances into the more highly metamorphosed area, to the north and east of Dalmally, sills, which would be designated epidiorites and chloritic schists further to the south, have now become recrystallised, and are true hornblende-schists and hornblende-gneisses, in which the hornblende is usually dark and fresh, and biotite is frequently present, with occasional garnets. Porphyritic felspars are often well preserved and conspicuous, as in some of the sills on the Glen Lochy side of Ben Sroine. Where sills are large they sometimes vary from a fine-grained hornblende-gneiss to a fairly coarse hornblende-rock showing scarcely any traces of foliation. These sills, however, are not nearly so common in the more altered area as in the district about Loch Awe.

Intrusive Rocks later than the Foliation of the Argyllshire Schists.

Various large masses of granite and innumerable sills and dykes of basic as well as acid material have invaded the schists of the south-western Highlands since the time of the production of the foliation. The question of the age of these intrusions is one of considerable difficulty. They not improbably belong to different periods of hypogene activity. Some of them no doubt belong to the time of great volcanic activity when the lavas of the Lower Old Red Sandstone of Lorne were poured forth. In the *Summary of Progress* for 1897 and also in that for 1898 reasons were given to show that the granite of Ben Cruachan not impossibly belonged to that volcanic period. No new evidence has been met with to impugn or to confirm this suggestion. On the present occasion it will be more convenient to discuss the occurrence of these eruptive rocks apart from the consideration of their geological date. They have recently been studied afresh both by Mr. Hill and Mr. Kynaston, and the observations of these two geologists will here be given in connection with their notes on the schists through which the intrusive rocks have been erupted.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

At the time of Mr. J. B. Hill's transference from Scotland to Cornwall, a large tract between Inveraray and Dalmally, on which he had been engaged was not finished. The completion of this area as well as the northerly extension of the work from Dalmally was assigned to Mr. Kynaston. As the different sedimentary series of the Loch Awe region often shade into one another imperceptibly, a more or less arbitrary divisional line had to be adopted, and in order to secure that these lines should be drawn uniformly on the same horizon, it was desirable that both surveyors should visit the ground in company so as to run

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District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

the boundary-lines continuously from the one part of the district into the other. MR. HILL was accordingly instructed to join his colleague for a short time for this purpose, and they conjointly completed the joining up of their boundary-lines along the limits of their respective areas—a total length of 40 miles. MR. HILL took advantage of the opportunity to revisit the mountainous country between Glenfyne and the Shira River for the reaxamination of the igneous rocks of Beinn Bhuidhe, and, as this work would probably have a bearing on the future survey of the ground to the northwards, he was accompanied by MR. KYNASTON.

The following description of the interesting and peculiar eruptive rocks of this district is supplied by MR. HILL. It is inserted here for convenience, but the age of the rocks must be much later than that of the Dalradian sediments which they traverse. MR. KYNASTON is of opinion that the Ben Cruachan granite not improbably belongs to the Lower Old Red Sandstone volcanic series of Lorne; while MR. HILL is disposed to regard it as of greater antiquity.

The occurrence of olivine-monzonite—a rock new to Britain—has been reported by MR. HILL in previous years from various parts of Argyllshire. He first mapped rocks of this kind in 1892 among the igneous masses forming the Beinn Buidhe complex, and apparently related to the great granite mass of Glenfyne. The following year he met with a rock identical in character on the western side of Loch Awe, close to the village of Kilchrenan. In 1896 he mapped a similar mass near Loch Avich about nine miles south-west of Kilchrenan, and described it briefly in the *Annual Report* for that year.* In the same *Report* a fuller account was given of a similar rock which MR. GRANT WILSON had mapped in the neighbourhood of Ballachulish.† During the past season MR. R. G. SYMES has met with another monzonite dyke in the Kilmelfort district (*postea*, p. 64), near MR. HILL'S mass at Loch Avich, while MR. KYNASTON has mapped an example in Glenorchy. Doubtless other instances of them may be found as the mapping of the South-Western Highlands advances. With the exception of those in the Beinn Bhuidhe area, the mode of occurrence of these rocks is too isolated to throw much light on their origin. At Beinn Bhuidhe, however, an assemblage of igneous rocks can be studied which merge into one another, and among which a definite relationship can be observed both in the field and by microscopic investigation.

The extensive granite masses of Glenfyne and Ben Cruachan are separated by a space of nine miles. In the intervening ground small bosses of granite, diorite, and olivine-monzonite appear, besides sills and dykes of orthophyres, porphyrites, and lamprophyres. The granite masses of Glenfyne and Ben Cruachan are similar in character, while the occurrence of smaller bosses of granite and diorite between them may indicate an underground

* Annual Report of the Geological Survey for 1896, p. 23

† *Op. cit.*, p. 21.

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connection between them—a connection further indicated by the enormous amount of the hornfels type of alteration on the Beinn Buidhe slopes, which is far in excess of what would be likely to be brought about by the small granite intrusions that appear on the surface. The western boundary of the Glenfyne granite is roughly coincident with Glenfyne. The dykes of orthophyre and porphyrite occupy a zone about a mile in breadth, and extend to about six miles south-west from this granite. None of them are seen to pass into the granite, but the porphyrites bear such a strong petrographical resemblance to it that there can be little doubt that they represent the dyke phase of that rock. District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

The distribution of the small igneous bosses, however, is somewhat different. They are scattered westwards from the Glenfyne granite over a broad tract of mountainous country extending to Glen Shira. If we except two small bosses of diorite which occur somewhat outside of this zone at about six miles south-west from the Glenfyne granite, it may be stated generally that the granite and diorite bosses occupy the part of the belt nearest to the granite, while the olivine-monzonites occur in the outer zone, the central part of the belt being more or less common to both, so that while the monzonites extend to a distance of about four miles from the granite, the small bosses of granite and diorite are restricted to a zone extending about two miles from the Glenfyne granite. Again, the lamprophyres of monzonite type are most strongly developed in the monzonite area, but also extend in a northward direction as far as Dalmally, helping still further to bridge over the interval between the main granite masses of Glenfyne and Ben Cruachan.

Before entering further into a description of these olivine-monzonites and their allied rocks, it will be convenient to state briefly the sense in which the term monzonite is here used. While this group of rocks bears marked affinities to the rocks described by Brögger as monzonites from the district of Monzoni, the Argyllshire type-rock is more basic, and always contains olivine, and while the olivine-bearing monzonites would represent only a basic variety of Brögger's group, in Argyllshire this represents the type-rock. But in other respects they resemble so closely the monzonites of Brögger that the term olivine-monzonite, first applied to them by Mr. Teall,* has been adopted. As shown by Mr. Teall,† these rocks are allied to both picrites and to monzonites, the amount of augite and olivine linking them with the former, and their proportions of silica, alumina and magnesia with the latter. Mr. Teall further pointed out that the augite from the rock mapped by Mr. Grant Wilson near Ballachulish was of the same type as that occurring in the "augite-syenites" of Monzoni. While, again, some of the rocks from the Loch Awe and Inveraray district exhibit a more or less equal amount of orthoclase and plagioclase, and in this respect approach closely to the monzonites of

* *Op. cit.*, p. 23. † *Op. cit.*, p. 22.

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District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

Brögger; this character is by no means persistent in them. In some good olivine-monzonites, fairly typical of the Argyllshire rocks, orthoclase has diminished to a very small proportion as compared with the plagioclase, and this diminution holds good whether or not the rock is rich in olivine.

In the field these monzonites present a characteristic appearance. They occur as more or less lenticular-shaped masses, like coarse dolerite, with a strong tendency to weather into cup-shaped depressions or deep hollows. In decomposition, however, they bear a striking contrast to dolerites; their outer surfaces are remarkably fresh, and ring somewhat like phonolite when struck with the hammer. They are dark in colour, and their constituent minerals can be readily detected with the naked eye. Pale green olivine in fairly large rounded grains can be seen amongst the more conspicuous dark augite and brown biotite, the felspar being less conspicuous. Perhaps the most characteristic mineral which strikes the eye is the biotite, in a discontinuous, patchy condition, but with the patches in optical continuity. When hypersthene is present, it can generally be readily detected without the assistance of a lens. Sometimes large patches of the rock are almost entirely felspathic, but these bear an insignificant proportion to the mass as a whole, which is generally fairly uniform throughout.

In this Beinn Bhuidhe region there are two well marked examples of the typical olivine-monzonites. One mass occurs in the Brannie Burn a mile south-south-west of Beinn Bhuidhe, the other in the Allt an Sithein, a tributary of the Shira River, about 2½ miles west of Beinn Bhuidhe. The olivine-monzonite in the Brannie Burn extends for a length of about half a mile in a broad lenticular mass. Its boundaries are largely obscured by drift, but its general outline can be sufficiently made out by its junctions with the schist seen in the main burn and its tributaries. It has been intruded in the well-marked zone of garnetiferous mica-schist, which has been traced across the Highlands, occupying a position between the Loch Tay limestone and the Ardrishaig series. This is a typical olivine-monzonite, dark grey in colour, medium-grained in texture, and with the usual rugged type of weathering. Olivine in good-sized grains is conspicuous; the biotite is likewise prominent amongst the augite and felspar; while ophitic orthoclase is exceptionally well developed. The rock has produced well-marked contact alteration in the garnet-schist, good hornfels having been developed for a distance of 15 or 20 yards from its margin. In the hornfels zone fresh bright red garnets are seen, which appear to have resulted from the re-crystallisation of the garnets that were present in the schist before the monzonite intrusion. The eruptive rock is fairly uniform throughout, but contains inclusions about six inches wide of very much finer grained material. There is also a zone about six feet wide within the mass, mainly made up of felspathic material, which probably represents the more acid condition of the magma; it passes insensibly into the normal rock, and is not unlikely to be of sedimentary origin, as it differs both

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in composition and in the absence of the hornfels alteration from the sediments on the margin of the mass.

District between Inveraray and Loch Awe. (Mr. J. B. Hill.

Perhaps the most interesting point in connection with this olivine-monzonite is the occurrence of a granite in the heart of the rock, as exposed in the small burn that flows through the northern part of the mass. The precise outline of the granite cannot be determined owing to the presence of drift, but the distance of its two outer margins from each other, as exposed in the burn, amounts to about 170 yards. It is a fine-grained hornblende-biotite-granite, of the type common in the Beinn Bhuidhe district. Its intrusive character into the monzonite is unmistakable, as it sends veins into it from its margin, while veins of granite six to nine inches wide traverse the monzonite.

The next exposure of the rock occurs at An Sithein, and this mass is rather smaller than that of the Brannie Burn, since it is little more than a quarter of a mile in length and about one-sixth of a mile in width. It has been intruded into the Ardrishaig series—a zone of calcareous sericite schists. Here the conditions for regional metamorphism were less favourable than in the schists at Beinn Bhuidhe, and the rocks therefore were neither so indurated nor so crystalline when the intrusive rock was injected into them. As a consequence the monzonite has been able to effect greater contact-alteration; the change into hornfels extends to about twenty yards from the intrusion, and is specially marked. In general character this dark grey, medium-grained olivine-monzonite is similar to that just described. It contains, however, not only olivine, but hypersthene, and is therefore a connecting link between the monzonites and the hyperites. Like the rock of the Brannie Burn it incloses small zones of more highly felspathic material. At its eastern boundary it is much coarser, owing to the augites being much larger than in the normal rock, and occurring in a porphyritic condition. This rock, like that already described, has been cut by a later intrusion; while the Brannie Burn mass was invaded by a granite, this mass has been pierced by a lamprophyre dyke.

A rock which, in the field, can be seen at once to belong to the monzonite group, occurs half a mile north-west of Clachan Hill, and about a mile from the Brannie Burn mass on the steep slope between that hill and stream. It is a large sill-like intrusion, about half a mile in length, and one-eighth of a mile in width, and strikes at the Brannie Burn rock, from which it is separated by a space of three-quarters of a mile. This mass, while closely allied to the olivine monzonites, is an augite-diorite. Mr. Teall, who examined it under the microscope, describes it as being composed of nearly colourless augite, biotite, hornblende (green), plagioclase and a little interstitial quartz. Alkali felspar has not been definitely recognised, and only a very small quantity can be present. The augite is of the type occurring in the monzonites. Although not itself a monzonite, the rock belongs to that group.

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District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

A small sill close to the mass just referred to evidently belongs to the same group. It contains no augite, and has been determined by MR. TEALL from microscopic examination to be a biotite-camptonite, exceptionally rich in ferro-magnesian constituents. There can be little doubt, however, that it is closely related to the rock last described, and represents a more basic intrusion from the same magma. Further, this rock must be regarded as a connecting-link between the lamprophyres and the monzonites. In the Brannie Burn ground the monzonite and augite-diorite are associated with large numbers of lamprophyres, which immediately succeed them and extend in a westerly direction to Glen Shira. These rocks occur in close proximity to the augite-diorite and monzonite, and many of them shade so indefinitely into them that we must suppose them to represent the dyke phase of the monzonite group.

Two small lamprophyre sills on the slope of Ceann Garbh, about two miles to the north-east of Beinn Bhuidhe, are in some respects peculiar. They occur near one another, are dark in colour and medium-grained, but contain porphyritic crystals of augite and platy plagioclase, and are undoubtedly allied to the monzonites. They are, however, distinctly more porphyritic than the typical monzonites, and in mode of occurrence are more closely akin to the lamprophyre division of the monzonite group. Under the microscope they are seen to contain fairly large phenocrysts of colourless augite and plagioclase, in a matrix of felspar, biotite, and magnetite (accessory), with which chlorite and other secondary minerals are associated.

Another example of a lamprophyre sill of monzonite type appears a little to the south of Dalmally. It closely resembles both the two examples just described from Ceann Garbh and the augite-diorite from Clachan Hill. It is an augite-lamprophyre that clearly belongs to the monzonite group. As the two sills from Ceann Garbh might equally be classed with the monzonites or with the lamprophyres, so this sill might be placed either with the augite-lamprophyres or the augite-diorites, seeing that it occupies a position somewhat intermediate between the two, the rocks from all these localities being unmistakably members of the monzonite group.

In like manner a passage may be traced between the lamprophyres of pronounced monzonite type and the lamprophyres of the typical camptonite type. These intermediate stages can be favourably studied amongst the numerous lamprophyres of the Brannie Burn. In some instances augite is as conspicuous as hornblende, while in others hornblende only occurs, and we get the typical camptonite or hornblende-lamprophyre of this district. In some sills phenocrysts of altered augite and brown hornblende may be seen in a matrix of the lamprophyre type, while in others, by the absence of augite and the addition of biotite, we get a biotite-camptonite. Some of the sills, again, are made up of material similar to the ground-mass of these camptonites, and by the gradual diminution of the hornblendes we reach a type of lamprophyre prevalent in the district.

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District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

The monzonites, although most common amongst the more basic rocks of the district, are not wholly confined within such range. An instance will now be described in which a monzonite forms a portion of a mass which, taken on the whole, is a hornblende granite or a tonalite. About a mile and three quarters south of Beinn Bhuidhe two small bosses occur at rather more than a mile from the boundary of the Glenfyne granite, but not more than a third of a mile from the schist which is veined by the granite. The larger mass is about a quarter of a mile in length and one eighth of a mile in width. The smaller and more northerly mass, only separated from it by a distance of 100 yards, is about 200 yards long and about 100 yards wide.

These masses of fine-grained granite are slightly variable in composition and texture. In some parts the material is a grey biotite-granite or granitite, containing zonal plagioclase and interstitial quartz and orthoclase, in other parts hornblende appears. Moreover, the outer portion which is finer-grained is much darker and the amount of hornblende in it must be greater. Indeed it would appear that the margin of the mass is probably more basic than the interior, and since plagioclase felspar is in excess, parts of the mass might be more fittingly called diorite. Besides hornblende, augite is sometimes present. The specimen which Mr. Teall examined was composed of more or less idiomorphic augite, biotite, lath-shaped plagioclase, interstitial quartz, and orthoclase, with some accessory magnetite and secondary hornblende and chlorite. This rock is allied to both olivine-monzonite and to hyperite. Augite diorites occur in the monzonite group. Mr. Hill believes that the group may have a still further extension and embrace the more acid diorites and hornblende granites.

The district includes rocks still more acid than those now described. They consist of grey fine-grained biotite granites, forming small protrusions on the ridge and flanks of Beinn Bhuidhe, one of which has already been referred to as an intrusion in the olivine-monzonite of the Brannie Burn. There is every reason to suppose that these biotite-granites and hornblende-granites are of the same age as the Glenfyne granite, on the border of which they occur, and the finer-grained portions of the Glenfyne granite is identical in character with the material of these smaller intrusions.

While the instances here cited of a monzonite being pierced by granite and by a lamprophyre afford an indication of the relative ages of the rocks, they supply no evidence to determine the relation of the granite and lamprophyre to one another. This, however, has been apparently settled on the northern flanks of Beinn Bhuidhe, where a granite pierces a lamprophyre. The lamprophyre sill is distinctly seen to be veined by the granite which has produced great contact-alteration on it. Under the microscope the older rock is found to be composed of small scales of contact-brown-mica and water-clear plagioclase crystals, and crystalline patches of hornblende are also seen.

From the occurrences and behaviour in the field of this in-

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District between Inveraray and Loch Awe. (Mr. J. B. Hill.)

teresting group of rocks, we may now proceed to consider how far they help in determining the relations of the various igneous rocks apparently scattered at random over the wide district of rugged and somewhat precipitous hills, amongst which the highest peak, Beinn Bhuidhe, rising out of Glenfyne, attains within the space of 2 miles from its base an elevation of over 3,000 feet. The rocks enumerated in the foregoing pages range from acid to basic in composition, including granite, quartz-diorite, augite-diorite, augite-camptonite, camptonite, lamprophyre, and olivine-monzonite, which are so closely connected from a petrological standpoint that they pass by insensible gradations into one another. We have seen that the monzonite type prevails over the entire series, linking them together as a connected whole. This prevailing monzonite type, embracing rocks so varying in composition, is strong presumptive evidence that the rocks represent various phases of material which has been derived from a common magma. Further direct proof has been obtained of the intrusion of different members of the group into one another, thus affording an indication of the order of the successive phases of injection. If this apparent order accurately represents the true sequence of events, the olivine-monzonites would appear to have been intruded first, followed by the lamprophyres, and finally by the granite, or in other words, that the more basic material was intruded earliest, and the most acid latest. Whether the smaller igneous masses of the Beinn Bhuidhe area coincide in age with the large granite mass of Glenfyne cannot be with certainty maintained, but, as stated already the smaller granite masses appear to be identical with the finer-grained portions of that granite, and the porphyrites which occur amongst them are so closely allied to it, that there can be little doubt that they represent its dyke phase. On the whole there are strong grounds for supposing that all these granite masses are approximately of the same age.

The study of this group of rocks throws some light on the age of the lamprophyre-dykes so generally scattered over the Highlands. So far as the lamprophyres of this district are concerned, the evidence is ample that, like the olivine-monzonites, they have been derived from the more basic portions of the magma, which afterwards supplied the material for the granites. It is not suggested that all the lamprophyre-dykes are necessarily of the same age, nor that each granite mass was intruded at precisely the same time. Some of the lamprophyres are possibly later than some of the granites, but we have no reason to doubt that the order of succession here described holds good generally —at any rate the evidence is absolutely conclusive that some lamprophyres have preceded the granite of their vicinity.

Allusion has been made on a previous page to a group of porphyrite-sills extending to the south-west of the Glenfyne granite, some of which undoubtedly represent the dyke-phase of that rock. They are of three types, viz., orthophyres, porphyrites, and mica-porphyrites. The orthophyres are not so strongly developed as the porphyrites. They are rather unsatisfactory in

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District between Inveraray and Loch Awe. (Mr J. B. Hill.)

character, the decomposition of their felspars having proceeded so far that it is not always possible to decide whether this mineral is orthoclase or plagioclase. The porphyrites are of two types and of different age. The mica-porphyrites are sometimes cut by the hornblende-porphyrites. They were themselves originally hornblende-porphyrites, in which the hornblendes are now represented by pseudomorphs of biotite and epidote. MR. TEALL has suggested that the alteration has been brought about as a result of contact or thermo-metamorphism, as hornblendes frequently decompose to aggregates of chlorite and epidote, while chlorite may be converted into biotite by contact or thermo-metamorphism. Certainly the evidence previously adduced of the alteration of a lamprophyre by contact-metamorphism is suggestive, the hornblende-lamprophyre being converted into a rock made up of water-clear felspar and contact-brown-mica. As regards the porphyrites there is no evidence of such contact-metamorphism, except that they occur amongst schists, in which the regional metamorphism is beginning to be rapidly increased, and it is possible that thermo-metamorphism may have been the agency responsible for this increase of regional metamorphism, and that the porphyrites were affected at the same time.

The rocks of the later group of hornblende-porphyrites are comparatively fresh, and vary largely both in their texture and porphyritic characters. The finer-grained varieties are hornblende-porphyrites, containing sphene; the porphyritic felspars are plagioclase, similar to the idiomorphic felspars in the Glenfyne granite, which also contains sphene. They generally also contain free quartz, sometimes in considerable quantities. As they become coarser in texture, they pass into quartz-diorite or hornblende-granite, and it may be noted in this connection that the coarser and more granitic varieties enter the zone of the monzonite group, the true dyke-rocks being most prevalent to the south-west, at and beyond the limits of this zone. A sill which occurs on Clachan Hill, about three miles south-west of Beinn Bhuidhe, is composed of hornblende, biotite (idiomorphic), and more or less lath-shaped plagioclase, alkali felspar, and quartz with sphene, apatite and iron ores as accessories. This rock is richer in ferro-magnesian minerals and plagioclase than a specimen selected as typical from the Glenfyne granite, and is somewhat intermediate in structure between granite and porphyrite. This group of hornblende-porphyrites somewhat differs in character from the porphyrite-dykes of the Loch Awe district, which MR. KYNASTON supposes to represent the dyke phase of the Cruachan granite. On the whole, the rocks which it embraces are more acid and contain a larger amount of quartz which is clearly distinguishable without the aid of a lens.

Although the Glenfyne granite has its own assemblage of smaller intrusions, dykes, and sills distinct from those belonging to the Cruachan granite, there are well-marked resemblances between these two great granite masses. Thus MR. KYNASTON has recorded augite-diorite from the district of Ben Cruachan, while according to MR. HILL'S observation, the igneous masses

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of the Beinn Bhuidhe area are suggestive of an underground connection between the granites of the two mountains. As regards the age of the Glenfyne granite, no definite statement can be made, except that it must be later than the foliation of the schists.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

The mapping of the Glen Etive granite was completed, and its boundary line was carried from Glenkinglass past the western end of Loch Dochart and thence in a general north-westerly direction to Lairig Dochart, where the line was joined up with that traced from Glen Etive in 1898. The rock has not presented any new features. The completion of the boundary-line shows that this granite forms a well-defined oval mass, almost completely surrounded by the Ben Cruachan type. It includes an area of approximately 60½ square miles, and is only covered to an insignificant degree by morainic material and other superficial accumulations. It is characterised by a wild and imposing type of mountain scenery, embracing no less than five peaks more than 3,000 feet in height.

The Ben Cruachan type of granite was found to die out against the Glen Etive mass in Glenkinglass, about a mile east of Doire-nan-Saor. Following, however, the margin of the latter type north-eastwards for two miles, we again find the Cruachan type about a mile south-west of Loch Dochart. It rapidly widens from a breadth of only a few yards to nearly half a mile, and assumes a fairly coarse texture. It is a pinkish hornblende-granitite, becoming fine-grained and dioritic in appearance at its junction with the quartzose schists to the east. North of Loch Dochart the boundary-line was traced in a general north-easterly direction to within a hundred yards or so west of the summit of Stob Ghabhar (3,565 feet). This portion of the Cruachan granite is continuous with that already mapped in Glen Etive, and it still maintains characters similar to those previously described from the Ben Cruachan district. In some places, for example, on the east side of the Dochart Burn, it appears to pass gradually into the Glen Etive granite. Its texture does not change as the margin is approached and the two types of rock pass gradually into one another, so that no hard-and-fast line can be drawn between them. A similar passage has already been noticed as occurring to the west of Loch Etive.*

Outside the eastern margin of the Cruachan granite a separate mass, of a similar general type, has been mapped in the immediate neighbourhood of Clais-gobhair. It is exposed for a mile and a half in the Clais-gobhair Burn, and is continued north-eastwards as a narrow strip to the north-western margin of Sheet 46., The rock is a medium-grained greyish, and sometimes pinkish, hornblende-granite—or, perhaps more strictly speaking, a diorite of the tonalite type. Close to Clais-gobhair an oval mass of a coarse very hornblendic diorite occurs within it, and doubtless represents a basic modification; while another small mass of a more basic diorite occurs among the schists close to its eastern

* *Summary of Progress* for 1898, p. 79.

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margin. Under the microscope the normal type of the hornblende granite [Slide, No. 8620, half a mile north-west of Claisgobhair] is seen to consist of plagioclase felspar, green hornblende, biotite, and a small proportion of alkali felspar and interstitial quartz; sphene, apatite, and iron ores occurring as accessories. The basic modification which occurs within this mass varies from a fairly coarse rock, containing about equal proportions of hornblende and plagioclase, to a coarse hornblende rock in which scarcely any felspar is visible to the naked eye. The former variety is seen under the microscope [8621] to be in great measure made up of large plates of green hornblende, which include small idiomorphic plagioclases and some small flakes of altered and ragged biotite. A few small pyroxene grains are also present, while hornblende and plagioclase likewise occur interstitially between the large plates of hornblende. There is no quartz. The other intrusion occurring outside the hornblende-granite is a similar rock, though the proportion of felspar to ferro-magnesian constituents is apparently more uniform. Further to the east again lies the diorite of Rannoch Moor, which doubtless, when more fully investigated, will turn out to have close affinities with the hornblende-granite and diorite of Ben Cruachan and the Black Mount.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

As regards the age of the Cruachan granite, which has been referred to in the Reports of former years,* no fresh facts of any importance have come to light this year. Mr. Kynaston has examined microscopically the andesite which occurs in the Pass of Brander at a distance of about three-quarters of a mile from the nearest exposure of granite, but could detect in it no positive signs of contact-metamorphism. The andesite is not found in this district any nearer to the granite than this point, and it never occurs on the north-east or Cruachan side of the Pass of Brander fault. It is to be hoped, however, that more definite facts concerning the chronological relations of these two rocks will be forthcoming as the work in this and other parts of the district advances.

In connection with basic modifications of the larger masses of intrusive rocks attention may be called to the occurrence of olivine-monzonite on the west side of Glen Orchy. An elongated patch of this rock, almost a mile in length and an eighth of a mile in breadth, besides two smaller oval patches, probably connected with it, was mapped about a mile north of Catinnis in Glen Orchy, and seven miles from Dalmally. The rock varies from a medium grain, weathering like dolerite, and consisting apparently in large measure of augite, to a coarse-grain, in which the constituent minerals, olivine, augite, and biotite are easily seen with the naked eye. This coarse rock forms the greater part of the mass, and weathers into the characteristic small cup-shaped depressions already noticed by Mr. Hill. Under the microscope [8614] the olivine is seen to occur mostly in rounded grains, and seldom shows crystal outlines. It is fairly fresh, is traversed by

* *Summary of Progress* for 1897, p. 85; for 1898, p. 76.

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Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

numerous anastamosing veins of magnetite, and often occurs as inclusions in the augite. Augite and olivine appear to be present in about equal proportions, and, together with biotite, form the main mass of the rock. The augite chiefly occurs as large individuals with well-defined crystal outline, frequently showing a marked zonal structure under crossed nicols. It also appears in smaller grains and granular aggregates of irregular contour scattered throughout the slide. The biotite is strongly pleochroic and occurs in ragged flakes and patches, and several detached flakes are often seen to be in optical continuity. Felspar, together with some biotite and small augite-grains, fills up the interspaces between the larger individuals. Both orthoclase and plagioclase are present, the latter being distinctly idiomorphic, while the former is interstitial. Magnetite fills the veins in the olivine, and appears also as grains associated with both the olivine and biotite. MR. KYNASTON has likewise visited the Beinn Buidhe district described by MR. HILL (p. 48), and agrees with his colleague that so far as the present known evidence goes, it may not be unreasonable to conclude that the monzonites have been derived from the basic portion of the magma which supplied the granites, and are, therefore, approximately of the same geological age.

Throughout the whole area surveyed by MR. KYNASTON last year a large number of dykes and sills, having petrological affinities with the larger granitic masses, have been mapped. These show a wide range of variation both in composition, structure, and the relative proportion of the different constituents. They include quartz-porphyries, felsites, porphyrites, diorites, and lamprophyres, and these pass into one another through intermediate varieties. As regards distribution it is noticeable that the more acid types of sills are almost always found nearer the granite than the more basic varieties. The lamprophyres, however, frequently occur in the neighbourhood of the Ben Bhuidhe granite, and diorites occasionally cut that of Ben Cruachan.

The quartz-porphyries are found on Ben Mhic Monadh, about the head of Glen Strae, and in the Black Mount district. They traverse the schists and the Cruachan type of granite, but are not seen to cut the Glen Etive type. The usual type is a biotite-bearing quartz-porphyry, containing a certain amount of plagioclase as well as orthoclase. These, by an increase in the amount of plagioclase relatively to orthoclase and the disappearance of the quartz, will pass into porphyrites.

The porphyrites are common in the Glen Strae and Black Mount portion of the district surveyed, and also occur, but more sparingly, in other parts. They comprise both biotite and hornblende-porphyrites. The former pass occasionally through intermediate varieties into orthoclase-porphyries or orthophyres and quartz-porphyries, and the latter merge into diorites. Good examples of the more acid type of porphyrite are found in the neighbourhood of Clais-gobhair, and some of these are so crowded with phenocrysts as to have the appearance at first

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sight of a granitic rock. A specimen from Meall Buidhe shows abundant phenocrysts of felspar, biotite, hornblende, and small quartz-grains in a fine greyish matrix. Under the microscope [8624] all the larger phenocrysts of felspar are seen to be plagioclase, and to be in excess of orthoclase which occurs in smaller crystals. Quartz occurs sparingly in small, rounded grains. The biotite is seen as plates with ragged outline, and is also scattered throughout the rock in peculiar groups and patches of small flakes. These groups are frequently associated with hornblende, and would appear to be replacing it owing to some secondary action. The hornblende is pale green and occurs in irregular patches and grains, which never show crystal outlines, and the patches appear as a granular aggregate beneath crossed Nicols. Occasionally these patches have a more defined form, but they are always associated with numerous small flakes of biotite and grains of magnetite. Apparently there has been a gradual breaking down of the hornblende, and it is now partially replaced by secondary biotite and magnetite. Both the original biotite and hornblende occasionally occur as inclusions in the felspar. The groundmass is a micro-crystalline quartzo-felspathic aggregate with small disseminated grains of biotite and hornblende. Magnetite is an accessory. Another variety of hornblende-porphyrite with acid tendencies is common in the Cruachan granite on the ridge to the west of Stob Ghabhar, near Clais-gobhair. Elongated crystals of hornblende and plates of biotite are easily seen with the naked eye, while the felspar phenocrysts sometimes range up to an inch in length. The microscope shows [8623] that some of these latter are evidently orthoclase, though the larger proportion of the felspar phenocrysts are plagioclase. The hornblende is fresh and occurs in well-defined elongated crystals. The biotite is in about the same proportion as the hornblende and frequently occurs in hexagonal plates. Quartz occurs as an accessory; but is not visible to the naked eye, and only appears in occasional small rounded grains. The groundmass may be described as micro-dioritic. It shows much idiomorphic plagioclase, small greenish hornblendes, and biotite, with interstitial felspar and quartz. Porphyrite of this type has already been noticed from the same district.* These rocks appear to have closer affinities with the Glen Etive type of granite than with that of Cruachan.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

Diorites and micro-diorites, in which plagioclase and hornblende may often be porphyritic, are common as sills in the Glen Orchy part of the district and in the Black Mount. These appear more frequently in the schists than in the granite. An unusual type, but well-marked when it occurs, is found on Meall an Laoigh, three miles south of Clais-gobhair. It is an augite-diorite with conspicuous and well-defined porphyritic augites, giving the rock a peculiar spotted appearance. Sills of a similar rock have also been mapped on the high ground separating Glen Strae from

* *Summary of Progress* for 1898, p. 39.

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Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

Glen Kinglass.* The intrusions of this rock usually form larger sills than the porphyrites. In one instance, on Ben Larachan, a plug-like mass of the rock was mapped, roughly circular in outline. This porphyritic type of augite-diorite is not known to cut the granite. The proportion of felspar to augite and hornblende often varies considerably; it is in the more felspathic varieties that the spotted appearance above referred to is so marked. Under the microscope, a specimen [8622] from Meall an Laoigh, shows large porphyritic augites resembling the augite of the monzonites, though not so fresh, with well-defined crystal outlines and zonal structure seen under crossed Nicols. Marginally they are partially replaced by greenish hornblende. The rest of the rock is dioritic in appearance, and consists of plagioclase, green hornblende, biotite, and some accessory magnetite. The biotite appears in scattered flakes, often in groups in optical continuity, recalling a similar feature in the monzonite. This appearance seems to be due to the biotite being moulded on the felspars. The plagioclase is mostly idiomorphic, and there would appear to be also a certain amount of interstitial orthoclase, though all the felspar is so turbid from decomposition that this point cannot be definitely determined. It is interesting to note certain apparent points of relationship between this type of augite-diorite and the monzonites. The addition of olivine and the elimination of the hornblende would give a rock resembling the olivine-monzonite of Glen Orchy. Its mode of occurrence also resembles rather that of the monzonites than that of the ordinary porphyrite and diorite sills. The sill-like mass of this rock on Meall an Laoigh is cut by two small intrusions of quartz-porphyry.

The lamprophyres constitute a rather ill-defined group, between which and the diorites and porphyrites there seems to be no hard and fast line. They are found in large numbers in the Glen Shira and Ben Bhuidhe parts of the district, but in a northerly and north-westerly direction from the upper end of Glen Shira they gradually die out, and only occasionally occur among the hills between Glen Orchy and Glen Strae. Many of them have already been mapped and described by Mr. Hill. Frequently they are highly micaceous, resembling typical mica-traps. Varieties containing a large proportion of hornblende are common. A sill, previously mapped by Mr. Hill, north-north-west of Corryghoil, near Dalmally, is seen under the microscope [8615] to be a typical camptonite. It contains abundant idiomorphic brown hornblendes in elongated crystals, plagioclase, orthoclase, interstitial quartz, and accessory magnetite. Sills of this type are numerous in Glen Shira, Glen Orchy, and on Ben Sroine, between Glen Orchy and Glen Lochy.

Kilmelfort district. (Mr. R. G. Symes.)

During the past year Mr. Symes has continued his survey of the district between Oban and Loch Melfort. To the south of the area of the Lorne volcanic rocks, from Kilmelfort as a centre, he has mapped the schists and other crystalline rocks, which

* *Summary of Progress* for 1897, p. 92.

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emerge from under the Old Red Sandstone series. In the Duchara Burn dark calcareous slates are met with, which display a metamorphosed character. They have been converted into calc-silicate hornfels, and they are associated with epidiorite and limestones. Interbedded with these strata at least one sill of intrusive epidiorite may be observed, but as the sedimentary rocks are very much folded, it is quite possible that the successive exposures of epidiorite may be due to the reappearance of the same sill owing to folding. Above the second bend of the stream grey and black slates are succeeded by the great sill of epidiorite which caps Carn Duchara (3½ miles south-east from Kilmelfort), the highest point of the ridge. The fact that limestones and black slates are found on one side of this sill, and grey slates and quartzites on the other, seems to point to an order of succession; and as MESSRS. HILL and POCOCK have detected shale fragments in the quartzites, it may be inferred that the succession is an ascending one from the limestones to the quartzites. **Kilmelfort district. (Mr. R. G. Symes.)**

On the shore between Kames Bay, two miles south-west of Kilmelfort and Rudh'an Roin on the east, the schists have not been so much changed into hornfels as nearer the granite, to be afterwards referred to, but occur for the most part as phyllites with calcareous bands, which at one point swell out into bands of limestone, or perhaps dolomite, folded upon themselves so as to be repeated over and over again. Sometimes these folds are isoclinal, though they often appear to be regular, the direction of cleavage seeming to be almost invariable with a high south-easterly dip. South-east of Tralaig, three miles to the north-east of Kilmelfort, thick limestones without shales are folded with the epidiorites. These strata reappear to the east of Loch a' Chaoruinn and of Loch a' Mhinn, where they form a small escarpment on which lies the basal breccia of the Lower Old Red Sandstone. East of Loch na Sringe, seven miles north-east of Kilmelfort, thick limestones folded up with siliceous schists, epidiorite, and black slates, are overlain unconformably towards the north-west by the andesitic sheets of the Lorne volcanic series. Most of these limestones could be used for economic purposes. West of Loch a' Chreachain (three miles east from Kilmelfort), and of Loch a' Chaoruinn, numerous thin bands of limestone again form rapid folds with epidiorite and black schists, and on the south pass under the Lower Old Red Conglomerate, from which they again emerge at the southern outcrop of the conglomerate in Gleann Mor Burn. The calcareous members of the schistose series have a wide extension in this region. Ten miles to the south of Kilmelfort, in the road east of Salachary, limestones with pebbles of quartz sometimes an inch in diameter are flanked with schistose epidiorite.

Besides the limestones, the sills of epidiorite form conspicuous features in the geology of this district. Thus, the great sill of Carn Duchara, already referred to, is a thick sheet, which seems to be repeated in rather sharp folds. The rock of this sill is highly basic and rather fine-grained, so that it has been

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Kilmelfort district. (Mr. R. G. Symes.)

susceptible of marked cleavage over the greater part of its extent, the cleavage-planes being nearly vertical, but inclined to the south-east. Near the top of the hill in several places grey slates are seen to be folded with the epidiorite, and again further to the north, beyond Loch a' Ghille, thin cakes of slate are seen adhering to the surface of the sill, and minutely crumpled along with it. If, as is probable, this marks the upper surface of the sill, it conforms almost exactly to the form of the ground. About quarter of a mile north-east of Loch a' Ghille a second sill, or perhaps a branch of the one under consideration, is quite like the first in texture, having porphyritic crystals scattered through the fine light-green groundmass. Along the north face of the hill the denudation of the folds in the epidiorite has exposed the underlying dark slates, which coincide with hollows, whilst the edges of the epidiorite sheets form crags. The first few feet of this sill lying next to the dark slates present a highly vesicular and amygdaloidal texture, the cavities being small and globular, and only elongated where they have been affected by the pressure which has been applied subsequent to the consolidation of the rock and the infilling of the vesicles. Where the kernels have weathered out the rock is so cellular as closely to resemble a lava, which the rock may possibly have been. The vesicular band follows each of the folds along which the black slates are exposed. On the south-western face of the hill the foldings seem to be more intense, for the upper porphyritic layers of the sill which make up the greater part of the ridge plunge at once vertically downwards, and are succeeded by grey flaggy slates, like the rock that adheres to the surface of the epidiorite, but quite unlike the underlying black slate associated with limestones. As to the rock of the hill itself, it is basic, fine-grained both above and below, and coarse-grained in the middle. In many parts the fine-grained rock has been cleaved into chloritic and epidotic slates or flags. Even where the rock is not much deformed by cleavage, it is highly epidotic and chloritic, which gives it a light sage-green colour. It also supports a crust of light-coloured lichen, which makes its crags conspicuous.*

To the east of Loch Pearson, close to Kilmelfort, epidiorites are again seen to be folded with quartzites, siliceous schists, and occasional phyllite bands. The quartzites dip about 15° east, their schistosity is inclined at an angle of about 80°. Mr. Teall, to whom specimens were submitted, remarks regarding the epidiorites of this place, "that they are not typical epidiorites, but being so closely allied to them must be grouped along with them." One of the specimens he describes as epidiorite (amphibolite, with zoizite and epidote), and of another he writes that "it contains chlorite, biotite, water-clear felspar, and a little quartz." Around Kilmelfort the epidiorites form great ridges,

* It may have been this highly epidotised rock, or some similar mass, especially the very vesicular part that has been the source of certain vesicular epidotic basic rock-pebbles in a conglomerate on the Island of Kerrera. See *Summary of the Progress of the Geological Survey* for 1897, p. 83.

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that stretch in the direction of the schistosity of the metamorphic rocks, the phyllites, quartzites, and limestones having been denuded on the lower ground. The tops of the ridges are strewn with massive angular blocks of the epidiorite. Kilmelfort district. (Mr. R. G. Symes.)

The most novel and interesting feature in Mr. Symes' recent surveys has been the discovery of a number of previously unobserved bosses of granite rising through the schists in the Kilmelfort district. These granites may be of the same age as that of Ben Cruachan, and they have produced a similar metamorphism in the surrounding sedimentary rocks.

Up to the present time six exposures of granite have been mapped to the south, east, and west of Kilmelfort. These are not improbably all extrusions from the same magma underneath. One of them occurs on the high ground four miles south-west from Kilmelfort, between Kames farm and Asknish on the south side of Loch Melfort. Another appears in the low ground at Tullich Farm, near Kilmelfort. Two hundred yards east of the manse a small exposure may be seen in the road leading to Loch Avich. Two other outcrops were noted in Gleann Domhain, four miles to the south-east of Kilmelfort, while one was found on the north shore of Loch a' Chaourinn three miles east from that village. Besides these bosses numerous veins cut the schists and epidiorites, and convert the former into hornfels. The granite, in all cases, is fine grained, with a preponderance of biotite, and the occasional occurrence of hornblende. In no part of this district has the granite been observed to make its appearance close to the Lower Old Red Conglomerate, nor have any blocks of it been found in that formation. Mr. Peach, who inspected the ground surveyed by Mr. Symes, found that "the Tullich granite is remarkably like some of the small bosses which occur about the Loch Doon granitic mass in Galloway." The phyllites as they approach the granite become a dark micaceous hornfels, and the calcareous beds are altered into calc-silicate-hornfels. Near the granite some of the strata assume a coarse gneissose structure, and probably contain cordierite.* At the south-east corner of the Tullich mass a dyke-like projection of the decaying granite appears to truncate a sill of felsite, showing flow-structure, intercalated between the bedding planes of the hornfels. The form of the granite mass suggests that the visible rock is the top of a boss from which the schists have not been entirely removed. In its centre a patch of schist may be seen adhering to the granite, while the schists are pervaded in every direction by strings of fine-grained granite, and, moreover, fragments of the schists have been floated off into the granite. The fine-grained character of the eruptive rock favours the supposition that nowhere is the granite now exposed far from its original margin.

On the hill-slope above Tullich, near the northern edge of the granite, a dyke of porphyrite about two feet across, and showing chilled edges, cuts the granite. A little farther down

* See *Summary of Progress* for 1898, p. 86.

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Kilmelfort district. (Mr. R. G. Symes.)

the slope a sill of felsite with flow-structure has been intruded along the bedding planes of the schists (here altered into hornfels), and appears to be truncated against the margin of the granite. As this sill, like that on the south-east corner, does not penetrate the granite, the granite would seem to be later than the felsite. It may be added that a vein of the granite occurs in the hornfels near the farm of Tullich on the west side of the felsite sill, as if the sill were cut by the granite, though the actual junction of the two rocks is not observable. The little isolated granitic mass on the road two hundred yards east of the manse changes the phyllites into hornfels, and the limestone into marble.

In all the area surrounding the several granite masses, the schists have been converted into hornfels. The limits of this metamorphism are not easily definable. In some cases hornfels may be observed without the visible presence of any granite; it may therefore be inferred that there may be considerable bodies of granite below ground, which, though they have affected the overlying strata, have not yet been laid bare by denudation.

Among the various instances of the occurrence of monzonite already referred to (*ante*, p. 48), allusion was made to one observed by MR. SYMES. It forms a dyke twenty feet broad, running in a north-west and south-east direction south of Lochan a' Bhailis, six miles north-east of Kilmelfort. No other example of the rock *in situ* has yet been detected in the district. A large erratic, probably from the same dyke, but not from the same locality, is to be seen on the Avich road, a little north-east of Lagalochan.

Two masses of highly crystalline porphyrite were mapped east of Kilmelfort. One of these occurs on the north shore of Loch Losgainn Beg, and the other more to the east of Loch a' Mhinn. It may be inferred that from these sources the blocks were derived which form the bulk of the undermost layers of the Lower Old Red Conglomerate in that neighbourhood. At Rudh 'an Tighe Loisgte, east of Kames Bay, several sills of pink porphyrite may be noticed which do not quite follow the bedding of the schists, but often pass obliquely across from bed to bed. These rocks present close-grained or chilled edges against the schist, and at least one of them is vesicular in the centre. Porphyrite-dykes are rather uncommon in this district in comparison with the enormous number of Tertiary basalt-dykes. Three examples of them can be traced from the south-east of Kilmelfort, in a north-north-east direction, cutting first the limestones, phyllites, and epidiorites, further north rising through the Lower Old Red Sandstone and its volcanic series, then once more through the schists and epidiorites east of Loch Tralaig, whence they hold on to the north, again traversing the Lorne andesitic lavas near Oban, and then striking for Loch Etive. Nearly all the porphyrite dykes, but more especially those seen cutting the Lorne andesites and Lower Old Conglomerate, have a north-north-east and south-south-west direction. A mile and a quarter north of Kilmelfort a porphyrite-dyke that cuts both the

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epidiorites and andesites assumes a columnar structure, where it traverses the lava sheets. Kilmelfort District. (Mr. R. G. Symes.)

Nearly all the margins of the porphyrite dykes show under the lens flow-structure. For instance, in a gully half a mile south of Loch Losgain Beg the porphyrite dykes are edged with "fluxion-felsite." A large mass of felsite rises on the hill south of Kames Farm, near to the granite already referred to. Numerous dykes radiate from this felsite mass, which cut the metamorphic sedimentary series; but no felsite dykes have been found intrusive in the granite or Lower Old Red Conglomerate. On the east side of Loch nam Ban a rock has been noticed which has been identified by MR. TEALL as a lamprophyre, but its relations to the adjacent mass of porphyrite or felsite are not observable. Another dyke of lamprophyre cuts the epidiorite mass which bounds the felsite half a mile south-east from Loch nam Ban, and which has already been referred to as underlying the conglomerate, but here again the relations of the lamprophyre to the felsite are not shown. In the road section north of Lagalochan a dyke of lamprophyre as well as several of porphyrite are seen to cut through the epidiorite and the hornfels-rock in connection with it.

With the view of continuing and completing the survey of the Island of Jura in which MR. WILKINSON was engaged at the time of his transfer to England he was moved for a part of the year to Argyllshire, and he succeeded in mapping a considerable additional portion of Jura leaving no more than it is hoped will be finished during the present year. Island of Jura (Mr. S. B. Wilkinson.)

The part of Jura surveyed by MR. WILKINSON last year lay chiefly on the western side of the northern half of the island, and embraced an area of thirty-one square miles. No new feature of importance has been noted by him among the rocks recently examined. The quartzite continues to display the same uniform appearance of the bedding, concealing the system of folds by which the strata are no doubt often repeated. The apparently continuous inclination is towards the south-east at between 30° and 40°. On the western coast line, however, from Ruintallain Point, the strata lie at a lower angle, and are seen to be rolling about considerably. Fine cliffs and crags of these rocks rise on the higher ridges such as at Rainberg Mor, Dhu Bheinn, and Bheinn Breac. The fine grained epidiorite dykes, formerly noticed on the eastern side of the northern area of Jura, have been found to extend westwards into the area surveyed during the past year. The three more or less parallel east-and-west dykes stretch across Gleann Cloisdale, and can be traced to Gleann Dorch where they seem to die out. The dyke of similar material which traverses the island from Ardlussa on the east across the top of Beinn Bhreac does not quite reach the western shore, but stops beyond the south-western slopes of a hill called Ceann Min na Beinne Brice, where it is joined by a basalt dyke which is in contact with it for a few yards. Another epidiorite occurs almost on the summit of the hill just mentioned, running in a north-

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west and south-east direction. As formerly stated, although these epidiorite dykes have the same direction as the dolerite dykes of the Tertiary series, they are doubtless of much greater age.

Island of Islay. (Mr. Peach & Mr. Wilkinson.)

Great difficulty having been experienced in the determination of the geological structure of the Island of Islay, especially of its central and northern parts, a strong effort was again made to discover the key to this complicated district before the publication of the map. Accordingly MR. PEACH joined MR. WILKINSON in a critical examination of the more important sections. Their re-examination was highly successful, as will be seen from the following account which they have prepared of the results obtained by them.

The coast section between Portaskaig and Bonahaven, which had been mapped in great detail, was again critically examined. Between Bonahaven on the north and Na Feamindean on the south (a point on the shore about a mile north of Portaskaig) the strata were found to comprise five groups in the following descending order:—

5. Sandy shales and flags with ripple-marks and worm-casts (like the "Fucoid Beds" of Sutherland and Ross), with massive beds of cream-coloured dolomite.

4. False-bedded blue and white quartzite with ripple-marks and vertical annelid-pipes—thickness 100 feet.

3. Sandy, rusty, ripple-marked and worm-tracked shales and flags, with a thin band of dolomite.

2. Quartzites with a band of conglomerate locally developed near the top, containing well-rounded pebbles of granite and other rocks similar to those in the Portaskaig Conglomerate.

1. Portaskaig Conglomerate, charged with well-rounded pebbles of granite, gneiss, quartzite, limestone, &c., in a sandy dolomitic and sometimes shaly matrix; with intercalations of rusty-weathering dolomite and bands of quartzite.

A small fault or line of crush appears on the shore near the junction of Groups 1 and 2, which probably does not seriously affect the original relations of the rocks.

The section from Na Feamindean, south to Portaskaig, is almost a counterpart of the sequence given in the foregoing table; the members of the highest Group 5, being visible at Na Feamindean, and the Portaskaig Conglomerate at Portaskaig. The local band of conglomerate at the top of Group 2 is, however, absent, and a fault, probably of no great amount, occurs on the shore near the junction of Groups 1 and 2. It is apparent, therefore, that an important structural fault runs inland from the shore at Na Feamindean, whereby the highest beds (Group 5 of table) are thrown down against the exposure of the Portaskaig Conglomerate to the north. In various sections between Portaskaig and Bridgend, the Portaskaig Conglomerate rests unconformably on the Islay limestone and the associated blue and black slates; indeed, the Islay limestone and slates have furnished a large proportion of the pebbles present in the exposures of the Portaskaig Conglomerate of that region.

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From the evidence here given, it appears that calcareous rocks appear on at least three horizons in Islay in the following descending order:— Island of Islay. (Mr. Peach & Mr. Wilkinson.)

(*a*) Dolomites in Group 5 of table.
(*b*) Lenticular bands of dolomite in Group 1 of table.
(*c*) Limestone (Islay limestone) associated with blue and black slates, and unconformably overlain by the Portaskaig Conglomerate.

Sixty-nine specimens of calcareous rocks, taken from these horizons in Islay, have been tested by DR. POLLARD, who reports regarding them that the bands in Groups 1 and 5 are dolomites, while those associated with the slates beneath the Portaskaig Conglomerates are limestones.

The two confirmatory sections between Portaskaig and Bonahaven appear to indicate the original order of succession of the strata. After MR. PEACH'S departure, several weeks were spent by MR. WILKINSON in tracing the various subdivisions above enumerated over the inland area between Bridgend and Ruadh a' Mhail. The groups were found to be remarkably persistent, and to furnish valuable aid in working out the structure of that region. In general, it may be said, that they are repeated by a series of sharp folds, the long axes of which run north-east and south-west. In some cases, owing to faulting, only one limb of the fold is represented.

Island of Arran.

PROBABLE ARENIG ROCKS OF THE HIGHLAND BORDER.

In former Annual Reports of the Geological Survey reference has been made to the discovery of a band of rocks, possibly of Lower Silurian age, which have been wedged in along the fault at the Highland Border between the Lower Old Red Sandstone and the crystalline schists and grits.* These rocks have been traced at intervals from Kincardineshire to Dumbartonshire. They consist of graphitic shales, slates, or schists, black, grey and red cherts, and various dull green rocks of igneous origin, some of which are probably lavas, while others are intrusive. This association of black shales, cherts and volcanic and intrusive rocks, so closely a repetition of that which characterises the Arenig series over the Silurian uplands of southern Scotland, led to the suspicion that these Highland Border rocks might prove to be of Lower Silurian age. The suspicion was further strengthened by the finding of *Radiolaria* in the cherts, precisely as these organisms occur in the cherts of the Southern Uplands. A much more extensive development of probably the same belt of rocks has been detected far to the south-west in County Tyrone, where the igneous accompaniments are particularly conspicuous, embracing lavas, agglomerates and tuffs.†

* See *Annual Reports* for 1893, 1895, and 1896.

† A. Geikie, *Ancient Volcanoes of Britain*, vol. i., p. 240.

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North Glen Sannox. (Mr W. Gunn.)

During the past year another link in the long chain of evidence has been found by Mr. Gunn in the island of Arran, which thus connects the Stirlingshire section with those of Ireland. Though there is the strongest presumption that the rocks in question should be regarded as of Lower Silurian age, this account of an additional development of them is meanwhile retained in the present section descriptive of the Dalradian rocks, but further allusion will be made to them at the end of the account of the Silurian rocks (p. 82). Mr. Gunn has supplied the following notes regarding their occurrence in Arran.

A strip of rocks that can be separated from the ordinary schists of the island, has been found to be well developed in the valley known as North Glen Sannox. It crosses the glen from south to north at a distance of rather more than a mile from the sea. It is upwards of a mile and a-half long, and from 100 to 400 yards broad, having its narrower width at the northern end. The rocks in this strip of ground, so far as can be seen, are not separated by any structural line from the ordinary schistose grits of the Highland series, which they follow with no apparent break. Nor do they differ in degree of metamorphism from the contiguous Highland schists. A closer examination, however, reveals some characteristic features which have not been met with among the schists, but which precisely resemble those already detected in the supposed Arenig rocks of the Highland border. They consist of black shales or schists and cherts, with some bands of igneous rock, which probably include both volcanic and intrusive bands.

The black shales and cherts are associated together as they occur in Stirlingshire, and also in the band of similar deposits intercalated with volcanic rocks in the Arenig group of Ayrshire. The black shales are partly in the condition of phyllites and much corrugated in places. The cherts are appreciably granulitized, and resemble in structure those portions of the cherts which approach the granite of the Southern Uplands. In this condition such rocks have usually had their organic remains obliterated. No trace of *radiolaria* has yet been found in the Arran cherts. The most prominent members of this group of rocks are those of igneous origin, and the important fact has now been definitely ascertained in Arran, that they include undoubted lavas and volcanic agglomerate. They occur intercalated with the black shales or schists, and cherts, as bands of a dull-green, decomposing material, which may be most conveniently named in the meantime "greenstone." Like their associated sedimentary accompaniments, they have undergone some deformation, and have passed into the condition of epidiorite. So far as the examination of the rocks has yet advanced, the whole of them, igneous and aqueous, are in the same condition of metamorphism as the schists to the north and west of them. They have an apparent dip to the east or east-south-east, stand at high angles, even as much as 90°, but there is no means of deciding which is top or bottom of the series. They have undergone much plication, which is specially observable in

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the intercalations of black schist. They are flanked on either side by schistose grits of the ordinary Southern Highland type. The strip of rocks now described, is cut off at the southern end by the intrusion of the Arran granite, at the north-east end of Suidhe Fhearghas, while their northern boundary is a fault, which brings down against them a part of the Lower Carboniferous series. The schistose grits, which apparently underlie these rocks, are well exposed in the North Sannox Burn at the bridge, while another series of schistose grits, which apparently overlie them, can only be observed in the main stream, and on the south side of the glen, as they are cut out on the north side by the great Highland Border fault, which brings down the Lower Old Red Sandstone against them. This fault gradually crosses the line of strike of the igneous group, of which consequently only a portion is represented at its northern end. North Glen Sannox. (Mr W. Gunn.)

The general succession of the members of this group of rocks, together with the overlying and underlying sedimentary strata of the Highland series, is apparently as follows, in descending order:—

1. Coarse schistose grits or gritty schists, weathering with a smooth surface.
2. Thin bands of slaty schist, with traces of dark schist or shale, apparently alternating in places with thin bands of greenstone.
3. Upper bed of greenstone, generally fine-grained and quite schistose in places, with some lenticular bands of agglomerate.
4. Bands of light coloured and dark chert, associated with bands of laminated black shale or schist, and a band of schistose grit.
5. Lower bed of greenstone, often massive—it contains an agglomerate band on the north side of the valley.
6. Bands of black shale or schist, associated with chert, and with some fine-grained slaty schist.
7. Thick mass of strong and coarse schistose grit, sometimes greenish and different in character from No. 1.

The whole succession may be observed in the North Sannox Burn, and on the hillside to the southward. On the north side of the valley, the upper grit and greenstone are at first almost entirely concealed by glacial drift, and eventually cut off by the Highland Border fault. In the lower part of the section, the gritty schists are well exposed in the stream, both above and below the bridge, where the road to Loch Ranza crosses. They are here traversed by a few basalt dykes. About 70 yards to the east of the bridge, the coarser rock contains an intercalated band of fine-grained schist, and 80 yards farther down the stream, dark schists are seen to be associated with a brecciated rock, the like of which is met with in several places. It is composed of fragments of greenstone, but is not exactly like a true volcanic agglomerate. It may possibly have been produced by the brecciation of igneous rock while still in motion before complete consolidation. Above these rocks in the main stream comes the lower greenstone (5 in Table), which occupies the burn for a hundred yards. It is for the most part a massive rock, moderately fine-grained and of greenish-grey colour. It exhibits a well-developed "pillow-structure," identical with that of the basic

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North Glen Sannox. (Mr. W. Gunn.)

Arenig lavas of the Southern Uplands. The chilled and rounded margins of these "pillows," and the numerous amygdules, a short distance in from their surfaces, are marked features. The dark schist that apparently overlies the lower greenstone is much contorted in places, and is accompanied by a breccia similar to that just mentioned, and also by some bands of igneous material. The cherts which are associated with this black schist are well exposed, about 200 yards up the Allt Carn Bhain. Some of them are dark in colour, but the thickest bands seem generally to be light-coloured or grey. On the south side of the valley, the upper greenstone rests immediately on a strong gritty band; the former much resembles the lower bed, but with the "pillow" structure not so prominent. Its upper part is here and there so schistose that it might be taken for the so-called "green beds" of the Southern Highlands. A good exposure of the upper greenstone is to be seen on and about the two small hills called Cnocan Donna, where the doubtful Arenig rocks attain their highest point above the sea. On each of the knolls a band of true agglomerate is interbedded with the greenstone. These bands are lenticular, and are made up of angular fragments of fine-grained greenstone. Neither of them can be traced for more than 40 or 50 yards along the strike, and the more southerly is but five or six feet across at its widest part. The other is larger, and may be as much as 30 feet broad in one place. The upper schistose grits, only partly exposed in the main burn, form a prominent feature on the hillside 300 yards to the southward. and can be examined along the strike for a considerable distance in this direction till they in turn are cut off by the granite.

The lower greenstone forms prominent crags, one of which is a conspicuous object from the road, about 300 yards south-south-east from the bridge. The same sheet of rock is also conspicuous in the crags of Corloch, at the northern extremity of the strip, and it composes all the crags on the north side of the valley. There can be little doubt that these bands of greenstone are true lavas. They present many points of resemblance to the lavas of the Arenig volcanic series of Ayrshire.

At a distance of nearly 600 yards north from the main stream, and near the Allt Dornach, a rock which differs much in character from the lavas was the first igneous mass noticed in this part of the island, and was regarded as intrusive. This view has subsequently been corroborated by the results of petrographical examination. The rock, however, is probably nearly of the same date as the lavas. Only a few specimens of the rocks of this presumably Arenig band in Arran have yet been examined microscopically by Mr. J. J. H. Teall, who adds the following notes regarding them :—

"[8666.] Crocan-Donna, North Sannox. Fine-grained, greenish-grey massive rock, composed of minute prisms of nearly colourless hornblende, epidote, leucoxene after iron ores, quartz, and chlorite. This is evidently an altered basic igneous rock, a variety of epidiorite. [From the upper lava, No. 3 on the Table on p. 69.]

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"[8667.] Torr na Lair Brice, North Sannox. A scoriaceous rock, the cavities of which have been filled with calcite. The main mass is formed of microlitic felspar, chlorite, leucoxene, and carbonates. This, again, is an altered basic igneous rock. It differs from the above in containing recognisable felspar. It is closely allied to, but not identical with, the common forms of pillow-lavas. [This is the lower lava, No. 5 of the Table.] North Glen Sannox. (Mr W. Gunn.)

"[8688.] Torr na Lair Brice, near Allt Tornach. Moderately coarse-grained rock composed of patches of fibrous hornblende, relics of original deep brown hornblende, chlorite, plagioclase, epidote, and leucoxene. The original rock was probably a hornblende-gabbro. It may be termed uralitic gabbro. I have little doubt that this rock is intrusive. [This is the rock found near the Allt Dornach and referred to above as probably intrusive.]

"[8669.] Allt Carn Bhain, North Sannox, 200 yards from foot of burn. Similar to the last, but more highly altered. Chlorite and carbonates abundant. [There is not sufficient evidence on the ground to decide whether this rock belongs to the lavas or is intrusive.]

"The two fine-grained rocks [8666 and 8667.] are highly altered basic 'traps' (greenstones) allied to those found in association with cherts in other areas. The two medium-grained rocks are altered gabbros or diabases [8668 and 8669]."

SILURIAN.

The chief field-work of the past year among Silurian formations has lain in the east and south of Ireland, where the revision described in previous *Summaries of Progress* has been continued. Much attention has necessarily been given to the igneous masses which in these regions are associated with the Silurian rocks. Hitherto a large proportion of these masses has been mapped as consisting of lavas and tuffs contemporaneous with the formation in which they are intercalated. But as the revision has advanced, an ever-increasing body of evidence has been accumulating to show that rocks which have been mapped as "ashes" are often of intrusive origin, while some of them are grits or arkoses.

Counties Dublin and Wicklow.

In resuming field-work to the south of Dublin, MESSRS. EGAN and MCHENRY began by a study of the ground lying to the west of the great range of Leinster granite, where on the published maps a number of strips of "greenstone ash" are shown as intercalated among the Silurian strata. A careful examination of these rocks failed to disclose a single band of volcanic tuff, all the outcrops so represented on the map being either true felspathic grits or more or less crushed basic sills and dykes. Where the rocks have escaped deformation their true nature has generally been recognised, but the influence of terrestrial movements in inducing new parallel structures has only been recognised in recent years, so that it need not be matter of surprise that even portions of the Leinster granite were in some instances mapped as sedimentary material. District West of the Leinster Granite. (Messrs. Egan and McHenry.)

Among the principal localities at which ordinary sedimentary strata were mistaken for "ashes" may be mentioned the Deer-

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District West of the Leinster Granite. (Messrs. Egan and McHenry.)

park area west of Blessington, the river Liffey between Ballymore Eustace and Pollaphuca, and other places in the adjoining parts of the county Wicklow. Many other sections occur (Sheet 129), as, for example, in large quarries east of Dunlavin; also near Rathbran, west of Stratford, and in the country lying west and north-west of Baltinglass.

The crushed basic igneous rocks (in Sheet 129) were in all cases taken either for "greenstone ash" or, in the more intensely sheared portions, for Silurian sediments. Examples of both these identifications occur at Ballymooney, north of Donard; at Deerpark, south-south-west of Donard; and within the granite area at Colvinstown. Those at Ballymooney and Deerpark present features of special interest, seeing that some contain large crystals of felspar (Lambay porphyry type), while others pass gradually into amphibolite. The varied effects of the underground movements that gave rise to the deceptive appearance of bedding are well displayed there.

The results of his study of the microscopic structure of the grits and igneous rocks lying to the west of the Leinster granite has been prepared by MR. HENRY J. SEYMOUR, and will be found on p. 176.

In the portion of the county Wicklow west of the granite, acid igneous rocks do not occur. In the adjoining part of county Dublin, however, near Rathcoole (Sheet 111), dykes of felstone (mapped as "elvan") cut across the beds of slate. These resemble many of the felstones associated with the basic rocks east of the granite.

District East of the Leinster Granite. (Messrs. Egan and McHenry.)

On the east side of the granite (in Sheets 120, 130, and 139) rocks which have hitherto been regarded as occurring in the form of contemporaneous "ash" have been found by MESSRS. EGAN and MCHENRY to be either crushed igneous rocks or occasionally non-pyroclastic sediments. So far as these observations have yet gone, this correction has invariably had to be made. As the revision is carried southward in detail into the County Wexford, it remains to ascertain how far other areas really include contemporaneous "ashes." From a cursory examination it is surmised that true tuffs may possibly occur in the igneous area stretching south-west from Carrigadaggan* (north-west corner of Sheet 169) towards Waterford.

The oldest igneous rocks east of the granite are the basic varieties, which occur as ordinary diorites or as andesites. In Wicklow, examples are met with in the Bray Head railway-cutting, and at Greystones (Sheet 121). Southwards (Sheet 130) they exist a short distance south of Roundwood, and in the mountain overhanging the north side of the Upper Lake at Glendalough. Near Roundwood the rock is a variolite, slightly altered, the variety at Glendalough being partly amphibolite. and partly fine-grained diorite.

These rocks are largely developed in the south-east part of

* The name Carrigadaggan, which is not on the one-inch map, is that of a fossil locality, as published in the memoir of Sheet 169. It is a townland about seven miles east-south-east from New Ross.

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Sheet 130, especially in the Avonmore River valley south of Rathdrum, and in the vicinity of Westaston and Kilmacrea Upper, about three miles east and south-east respectively of Rathdrum. They also form knobs in the hilly ground near the coast in the vicinity of Rockfield House and Brittas. Many minor dykes of diorite also occur along the coast southward from Wicklow Head. District East of the Leinster Granite. (Messrs. Egan and McHenry.)

As a rule the true intrusive character of these basic rocks has been fairly recognised and expressed on the published maps; but where they have acquired a fissile structure from crushing and deformation they have been mistaken for sediments.

The microscopic characters of these rocks as developed near to, and at some distance from, the Leinster granite, have been studied by MR. SEYMOUR and will be found summarised on p. 176.

The acid rocks were less accurately treated by the older observers. Hence considerable modification of their mapping has been necessary. In all the cases hitherto examined the supposed "felstone ash" has been found to consist of crushed felstone of intrusive origin. Not only so, but in a large number of instances what have been regarded and mapped as interbedded sediments are really portions of true eruptive felsite, excessively crushed. Abundant evidence of both these conditions is found in the Kilmacoo mining district, south-south-east of Rathdrum (Sheet 130); also in the railway cuttings near that village, and along the river valley to the south. Fine sections occur on the coast at Ardmore Point; at The Castle: near Rockfield House; also in the Kilmacoo district just now mentioned. In many of these sections the rocks have a banded structure showing fine and coarse materials made up of broken felsites and pieces of sedimentary material. In some instances portions of pumice and lapilli have been detected by MR. SEYMOUR with the aid of the microscope, though the evidence on the ground indicates an intrusive origin. Instructive sections exist on the coast at Arklow Head, where many dykes of acid and basic rocks are exposed. The petrographical characters of the felsitic rocks of this region are discussed on pp. 179, 180.

An interesting and probably important point bearing on the age of the so-called "ashes" and acid "lavas" is the connection which MESSRS. EGAN and MCHENRY believe they have established between these rocks and the great granite ridge of Leinster. In many places masses which are mapped as "elvan," but are really granite, and some of which are acknowledged to be off-shoots from the main granite mass, pass into the "felstones" and "ash," as at Lewis Vale, two miles north of Arklow, and at Rock Little, two miles south of that town. The same transition is seen on a larger scale in the Croghan Kinshelagh district south of Aughrim, where a granitic rock, mapped as "ash," graduates into felstone on the hill at Kilmacrea Upper, east-south-east of Rathdrum. The Leinster granite was intruded into the Silurian formations before the time of the Carboniferous Limestone, and is thus presumably of the age of the Old Red Sand-

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District East of the Leinster Granite. (Messrs. Egan and McHenry.)

stone. The sheets of "felstone" connected with it cannot therefore be "lavas" of Silurian date. In the Croghan Kinshelagh district the shearing forces have affected the granite as well as the basic intrusions, and to such an extent that in many places the rock has actually been mapped as grey grits and slates.

One of the most novel features in the recent work of revision in Ireland has been the discovery of a number of cases of intrusive felsites, which present an internal finely brecciated structure so exactly simulating that of true volcanic tuffs that in hand specimens they would be unhesitatingly pronounced to be unquestionably of pyroclastic origin. The process by which they were produced is not yet satisfactorily explained, but this much may at least be asserted regarding them, that they form irregular eruptive bosses or dykes, and have been injected in veins and threads into the contiguous rocks. As far back as 1896* Mr. McHenry expressed an opinion that certain conglomerates in County Dublin, supposed to be of volcanic origin, had really been produced by intense crushing within the earth's crust, and at the same time he suggested that this might also have been the mode of formation of other masses in Wicklow and Wexford, which had always been looked upon as composed of truly volcanic detritus. During subsequent years this suggestion has been verified by the field-work of Messrs. Egan and McHenry in County Wicklow, and also by the microscopic study of the rocks by Mr. Seymour. Remarkable sections of these brecciated felsites are to be seen at Arklow Head, where their intrusive nature is shown. They are displayed still more clearly on the shore near Rockfield House (Sheet 130) between Mizen Head and Wicklow Head. They have always been regarded as tuffs, and appear as such on the Survey maps. An account of their minute structure by Mr. Seymour will be found on p. 179. Similar rocks were met with by Mr. Kilroe on the south coast of County Waterford and will be referred to in subsequent pages (see pp. 77–81, and 180). It may be added that in no instance have Mr. Egan and Mr. McHenry succeeded in detecting any volcanic detritus in the sedimentary strata near the igneous rocks, whether the latter are crushed or not.

Counties Dublin, Meath, and Down.

Slane, Bellewstown and Balbriggan. (Mr. McHenry.)

In order to prepare for the engraver the maps of those parts of the East of Ireland of which the Silurian tracts have been revised, it was necessary to re-examine the igneous rocks of these districts that the nomenclature might be brought up to date. In the counties of Dublin and Meath, towards the end of the past season, Mr. McHenry re-visited some special points in the Slane, Bellewstown, and Balbriggan districts, and was accompanied by Mr. Seymour, with a view to the petrographical study of the rocks. Mr. McHenry has supplied the following notes

* *Nature*, March 6th, 1896.

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of his re-examination. His recent work has confirmed him in the conclusions which he had formed in 1896, that the rocks which have hitherto been mapped as "ashes" in those districts are not of contemporaneous origin with the Silurian strata, but are really intrusive rocks, though in external and internal characters, closely resembling tuffs and breccias. The igneous rocks and associated breccias and "ashes" that occur along the coast at Balbriggan, and to the west of it at Herbertstown, are, in his opinion, basic intrusive rocks of one period, but of many varieties. They must at least be later in age than the Upper Silurian strata, which they penetrate, and, like the similar masses in South Dublin, Wicklow, and Wexford, they may belong to the great volcanic and plutonic series of the time of the Old Red Sandstone. In the Bellewstown Hill and Ardcath areas, respectively five and seven miles south of Drogheda, both acid and basic varieties occur, the basic being similar to those at Balbriggan in their general characters and mode of occurrence, while the acid varieties closely resemble those of Wicklow and Wexford. Again, a mass of igneous rock at Craig Barron, west of Slane (Sheet 91), mapped as felstone, has been ascertained to be really of basic composition (dolerite, etc.).

Slane, Bellewstown and Balbriggan. (Mr. McHenry.)

To the west of Slane various acid masses, mapped as felstone and felstone ash, have hitherto been regarded as contemporaneous with Lower Silurian strata. As some of them, however, are distinctly intrusive in the fossiliferous Upper Silurian series, they cannot be of Lower Silurian age, but from their very close resemblance in every respect to the Wicklow and Wexford types they not improbably belong to the same late period.

The two long east and west masses of rock mapped as "felstone" at Grangegeeth, three miles north of Slane, are now determined not to be igneous at all, but merely an arkose, composed of broken-up and disintegrated felspathic detritus in a fine green sandy matrix, which contains fossils in places.

In County Down a similar re-examination was undertaken by MR. EGAN of the abundant intrusions of igneous rock along the shore to the north of the mouth of Strangford Lough. He was accompanied by MR. SEYMOUR, whose notes on the petrographical results of the examination will be found on p. 180.

Co. Down. (Mr. Egan and Mr. Seymour.)

County Waterford.

The revision of the Silurian ground in the County of Waterford has been continued during last season by MR. KILROE, who has prolonged to its southern limit the line of boundary between the Lower and Upper Silurian formations. In this mapping the available evidence was entirely lithological as far as Kilmeadan, four miles west from Waterford, the strata proving barren of organic remains until, near that place in the railway cutting at Mount Congreve, they were found by the Fossil

Co. Waterford. (Mr. J. R. Kilroe.)

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Co. Waterford. (Mr. J. R. Kilroe.)

Collector, MR. R. CLARK, to contain double graptolites, probably indicative of Bala or Caradoc age. The boundary is crossed obliquely by bands of felsite, which, being highly cleaved, were represented as slate and grit on the published maps.

Caradoc strata in great variety, interspersed with igneous bands, are to be seen throughout the southern part of the County of Waterford (Sheets 178 and 179). They extend to the coast-line, and pass beneath the Old Red Sandstone of the Comeragh Mountains on the west, and of Dunmore and Brownstown Head on the east. Near the Upper Silurian area the strata consist of rapidly alternating grey grit and dark grey slate bands.

Similar slate and grit in larger bands are common further south; and black slate, containing, as at Garrarus, Caradoc trilobites, appears in many places. Green grits and epidotic slates, frequently calcareous and fossiliferous, occur in small isolated areas surrounded by igneous rocks in a triangular tract, which extends from Ballynamona southward to the coast and westward towards Durrow. These rocks have peculiar interest, as they are associated with the only true, scantily-represented volcanic tuffs that MR. KILROE has been able to detect in the region. The Bala or Caradoc strata also contain red grits, which are seen in a stream two miles west of Tramore, and associated with green grit and tuff at Sheep Island and at Knockmahon. Earthy limestones and calcareous grits rise into cliffs some 80 feet high at Dunabrattin, and 100 feet near Tramore, this group of strata attaining a visible thickness of 400 feet at the former place, and 650 feet at the latter. It appears also at Green Island near Annestown, and at several other points along the coast. The prevalence of Bala fossils at Tramore and Dunabrattin has long been considered to fix the stratigraphical horizon of these lime stones; and it is doubtful whether the interesting occurrence of Russian and Scandinavian Llandeilo forms, recently pointed out by MR. COWPER REED,* should be accepted as subversive of the conclusion.† The section seen at Carrigaghalia referred to later on, which MR. REED gives as corroborative of his opinion, is of very doubtful value, having regard to the great disturbances which have affected the region.

Black slate, which appears from beneath the limestone near Tramore and at Dunabrattin, may on account of its position, on lithological grounds and in the absence of fossil evidence, be assumed to be of Llandeilo age, like the black slates so distinctive of the Llandeilo formation all over Ireland. Similar black slate found in many other places in the district may in some cases be of the same age; in others, however, it belongs to a Bala

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* *Quart. Journ. Geol. Soc.*, vol. lv., p. 766.

† Especially in the absence of such forms from the Llandeilo limestone of Wales—a difficulty which the author admits. If the existence of these forms near Tramore be the result of migration westward, it would be reasonable to assume that they reached the Waterford area at a later epoch than the Llandeilo. Instances bearing out the presumption have been indicated by MR. MARR, and are referred to in MR. C. REED'S Paper, page 770.

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horizon, as is shown by its fossils. The relation of the black strata to the limestone is rarely manifest. Co. Waterford. (Mr. J. R. Kilroe.)

Mr. Cowper Reed reports the occurrence of *Dicranograptus* in black slate, which, dipping at an angle of about 80°, at present overlies limestone at Carrigaghalia, 450 yards south of the boat pier at Lady Elizabeth's Cove, near Tramore. In order fully to appreciate the bearing of this section it should be noticed that a continuous series of limestones and grits, visible in Newtown Cove, half a mile to the north of Great Newtown Head, runs inland for about 250 yards, and that the strike of these strata is fairly regular along the cliffs northward. A corresponding succession of limestones and grits might be expected to appear at Carrigaghalia, forming the cliff, and probably also proceeding inland. Instead of this development, however, the limestone is only seen at the base of the cliff, the cliff itself being formed of igneous rocks and the black slate, which is faulted. A thin felsite-sill and a massive basic one separate the limestone from the slate above, the slate being further penetrated by felsite higher up in the cliff, which is here crowned by another basic sill. The structure, therefore, is not regular and normal, so that any conclusion based upon the present position of the slate, relatively to the limestone, can hardly be well founded. The *Dicranograptus* slate would otherwise have to be taken to represent the fossiliferous calcareous grits of the glen at Newtown Cove, where no black slate occurs. The black slate at Carrigaghalia may be considered as in all probability a detached mass, caught in a group of igneous intrusions and carried upward out of its natural stratigraphical position. This view of its relations finds ample illustration in sections along the coast from Newtown Head westward, where similar detached masses of sedimentary rocks are to be seen, surrounded by igneous rocks.

Igneous Rocks of the Waterford Coast.

The igneous rocks of the County of Waterford have long attracted attention. Their varieties of composition, structure, and mode of occurrence have been noted, as well as the difficult problems which these varieties present to the geologist. Some notes on the petrography of these rocks by Mr. Seymour will be found on p. 180. The following petrographical types have been recognised in the field by Mr. Kilroe.

(1.) The oldest of the whole series appear to be light and dark-green andesites and other more basic rocks, such as diorites and diabases. The andesites are usually epidotic, and sometimes porphyritic, with crystals of augite.

(2.) Volcanic tuffs associated with Silurian grits, seen at Sheep Island, and other points along the coast. The contained fragments consist chiefly of felsite, sometimes perlitic, glassy or highly vesicular, with pieces of andesite and other more basic rocks and fragments of black shale.

(3.) Compact light-grey and pink potash-felsites, frequently vitreous and showing flow-structure, occasionally containing detached pieces of lime-

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Co. Waterford. (Mr. J. R. Kilroe.)

stone as in the sea-stack west of Sheep Island. At this point of the coast, the pink felsite is seen to break into a "breccia" which belongs to the next series.

(4.) Breccias—forming, for the most part, the coast between Great Newtown Head and Annestown, described on the published map in certain places as "felspathic ash" and "greenstone ash" and more recently regarded as "volcanic agglomerates." They are, however, intrusive rocks as will be more fully explained a little further on.

(5.) Green plagioclase-felsites, passing into andesites, and in certain places into "diorites." These prevail in the western part of the district, while the foregoing group predominates in the eastern. Similar rocks, however, form great dykes and sills to the east of Annestown, and may be seen along the coast as far as Great Newtown Head. At Sheep Island, offshoots from the dark green felsite of this group penetrate the breccia of Group 4, and massive sills of the same material invade and include between them an important lenticular band of strata consisting of fine tuff and green and red grit, the tuff graduating upward into the grit. The lower part of the upper sill displays a remarkably well-developed spherulitic structure in a band several feet thick on the south end of the island.

These green rocks—felsites, andesites, &c.—frequently assume a fragmental form like those of the previous group which are grey. They contain pieces of felsite of various kinds from small chips up to large blocks. In one remarkable instance, a little to the west of Ballydowane Bay, a sill consisting almost wholly of partially-rounded masses (the matrix being very scanty), includes some blocks more than two feet in diameter. Many of the lenticular bands in this group are cleaved, which no doubt led to their being mistaken for "greenstone ash."

(6.) Grey potash-felsite, usually porphyritic, which occurs in massive sills near Tramore and is recognisable along the coast to Ballyvoyle Head, near Dungarvan. It is probable that grey granite, similar to that of the Wicklow range, which occurs in lenticular areas trending south-westward, belongs to this stage of intrusion, inasmuch as one of the areas, north of Ballydowane Bay, seems continuous with that of a grey porphyritic felsite seen on the roadside near that bay. To this stage also belongs a striking porphyritic felsite with red felspar embedded in a green matrix, which occurs in two localities, north-east and south-west from Stradbally. Prismatic, spherulitic, and perlitic structures are occasionally to be seen among these felsites.

Green epidotic grits and fossiliferous slate of Bala age are seen to overlie the andesites of Group 1 north of Ballyscanlon Lough; while conglomerates, which form the base of the sedimentary series here and at Munmahoge, nearly three miles north-by-west of Tramore, contain pebbles almost wholly derived from similar andesitic rocks. It is, therefore, obvious that the Ballyscanlon andesites are more ancient than a portion of the Bala group, though there is no evidence that they were erupted contemporaneously with that group. No such satisfactory evidence of stratigraphical position is available for the determination of the age of the other andesites of the district; for while rocks closely resembling those of Ballyscanlon are to be seen in many places, they may be suspected to be of later date than the green Silurian strata. Some masses, however, to the west of Ballyscanlon, such as those of Corrig Castle Hill, near Ballylanneen, are at least older than the brecciated felsites of Group 4.

The tuffs forming Group 2 have been found in widely scattered patches, none of which perhaps exceed a few hundred square yards in area. They seem to be everywhere surrounded by later felsites.

Of the section at Sheep Island, the Director-General, who inspected the ground last summer with MR. KILROE, has fur-

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nished the following notes:—"A mass of pinkish-grey felsite rising out of the sea is surmounted by about 18 to 20 feet of well-bedded alternations of a fine breccia and of thin green shaly layers. The fragments enclosed in the breccia consist of small chips of highly vesicular felsites, andesites, and probably some more basic rocks. These materials are obviously of igneous origin. The most abundant of them are lapilli of a fine dull-green extremely minutely cellular pumice, which recalls the familiar basic lapilli of the Carboniferous tuffs of the basin of the Forth. They include also fragments of pink felsite with exquisitely perfect flow-structure. Many of the strata of this breccia are coarser at the bottom and become finer towards the top. There can hardly be any doubt that these strata are true tuffs. They pass upward at one place into some red shales and grits, the bedding of which is parallel with that of the tuffs below. Co. Waterford. (Mr. J. R. Kilroe.)

"Above this fragmental band comes another felsite, which is particularly conspicuous for the great perfection and beauty of its spherulitic and flow-structures. These structures are grouped parallel with the under surface of the sheet. The lower band of the rock is remarkably spherulitic. Some of the spherulites, composed of a very flinty pink felsite, measure three inches in length and many of them enclose a nucleus. Higher up in the sill bands of fine spherulitic material may be observed, the spherulites being small and round like peas, and scattered sparingly through the matrix. The lower portion of this felsite is traversed by a dyke two feet six inches broad, of a grey compact finely vesicular felsite."

The most important part of Mr. Kilroe's revision of the igneous rocks associated with the Silurian formations of the south of the County of Waterford has reference to the remarkable brecciated masses of that region. As in Wicklow and Wexford, these rocks have hitherto been considered as tuffs and agglomerates, but close re-examination of the remarkable coast-sections where the rocks are so well exposed, has led Mr. Kilroe to the same conclusion as his colleagues—Messrs. Egan and McHenry (*ante* p. 72). He believes that the main mass of the igneous rocks is of intrusive origin, and that most of the so-called agglomerates and breccias are not truly volcanic masses, but have been produced by a process of brecciation during the prolonged period of igneous intrusion. At the same time the microscopic study of the rocks by Mr. Seymour has shown that some of them are true felsitic tuffs, with glassy and vesicular lapilli.

The fragments enclosed in these "intrusive breccias," to use the term originally employed by Mr. McHenry, consist principally of various felsites and other igneous rocks, but include also, sometimes abundantly, angular pieces of black slate and grit, derived from the surrounding Silurian formations The felsite fragments often show flow-structure, and have obviously been derived from a rock such as that which may here and there be seen in veins and sills traversing both the igneous

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Co. Waterford. (Mr. J. R. Kilroe.)

and sedimentary masses of the coast-cliffs. Some specially instructive sections showing the character and relations of these rocks may be seen at Sheep Island, two miles west of Great Newtown Head, and on the adjacent part of the shore. Here the observer may follow, as it were, the successive stages in the process of the production of the brecciated structure in an intrusive molten rock. The original felsite has been broken up, and its fragments have been carried forward in a fresh inroad of similar material. The newer matrix sends veins into the included fragments, as may be well seen where the pale greenish grey felsite traverses a block of black slate. In some places, as at St. Ronan's Bay, south of Tramore, the quantity of included fragments sometimes amounts to about three-fourths of the whole mass, only one-fourth part being the matrix in which they are enveloped. It is difficult to realize how an intrusive rock so charged with foreign material could have been injected into cracks and fissures of the crust.

That this breccia moved as such, and was forced into irregular apertures or rents in previously solidified rocks is well displayed at many points of the coast-line. A remarkable section occurs on the cliff immediately behind Sheep Island, of which the Director-General has supplied the accompanying figure and notes :—

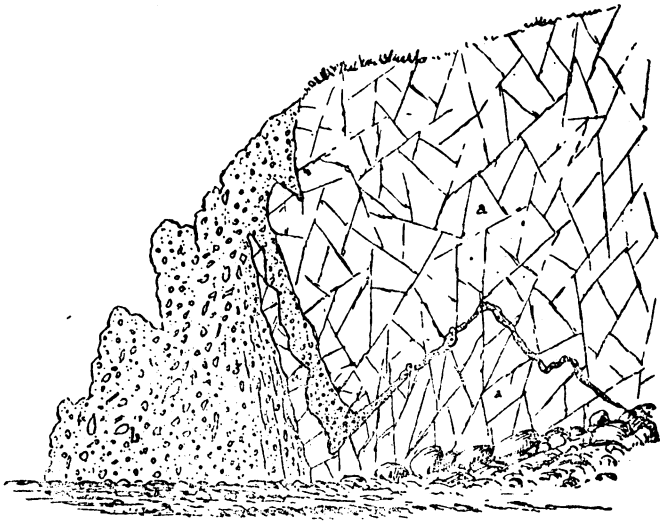

FIG. 1.—Section of Intrusive Breccia (*b*) in Felsite (*a*), shore opposite Sheep Island, south of Tramore, Co. Waterford.

"The older rock (*a*) of this section is one of the usual pinkish felsites which have so abundantly invaded the igneous and sedimentary masses of this coast. The younger rock (*b*) is a green 'breccia' of the prevailing type, but with a less proportion of included stones than may often be seen in other similar masses. The fragments which, however, are sufficiently numerous, consist largely of felsites, some having a beautiful flow-

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structure and others showing a vesicular texture. They include also pieces of a reddish limestone. It will be observed from the figure here given (Fig. 1) that this breccia is intrusive in the felsite It sends a long dyke or vein downward in the latter rock, of which it thus separates a strip at the margin. A little above the beach this dyke or vein bends sharply upward and rapidly lessens in thickness, but continues in a sinuous course through the felsite until it dies off in a narrow finger or thread. From the sharp bend just mentioned to the extreme end of the vein is a distance of seventeen feet. In the thicker dyke or vein to the left, the size of the stones is less than in the body of the breccia, and these are still smaller in the attenuated vein that strikes off to the right. But they continue to be present even up to the end.

Co. Waterford. (Mr. J. R. Kilroe.)

"The matrix is a fine felsite, about the true origin of which as a molten rock there could be no doubt if it were considered in itself and apart from the problem presented by its included stones. It has been obviously intruded here into an irregular rent, and its load of fragments has been as it were strained off by the narrowing of the passage until only fine chips were borne along to the end."

Petrographical notes on some of these interesting rocks have been prepared by MR. SEYMOUR, and will be found on pp. 179, 180.

If the majority of the igneous rocks of the Waterford coast, hitherto regarded as volcanic sheets intercalated contemporaneously among the Lower Silurian sediments, are now to be regarded as really intrusive in, and therefore later than these formations, the important questions remain of (1st) the geological era to which the prolonged injection of this enormous series of eruptive masses is to be assigned, and (2nd) the stratigraphical relations and age of the volcanic eruptions represented by the tuffs. As the intrusions have invaded all parts of the Lower Silurian series of the district, they are clearly of later date than these. North of Kilmacthomas MR. KILROE has found cleaved felsites closely adjacent to Upper Silurian strata. The sections are not conclusive as to the relations of the two groups of rock, but if the felsite is not brought in by faulting or folding but is really intrusive in the surrounding strata, it will follow that some at least of the protrusions cannot be older than some part of the Upper Silurian period. But the date may be more nearly defined by the evidence of the coast-line at Ballydowane Bay to which fuller reference will be made in the account of last year's field-work in the Old Red Sandstone (*postea*, p. 101). It will be shown that there is a high probability that the igneous protrusions of County Waterford belong to that remarkable period of hypogene and volcanic activity which witnessed the injection of so many of the chief granitic masses of the British Isles and the outpouring of such vast sheets of andesitic lavas and volcanic agglomerates and tuffs.

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Island of Arran.

An account of MR. GUNN'S interesting discovery of another exposure of the cherts and black schists on the Highland border has been already given in the section on the Dalradian rocks (*ante*, p. 68). But as these strata may with the highest probability be relegated to the Silurian system, a brief allusion to them again may not be inappropriate at the end of the foregoing narrative of recent progress among the Silurian formations of Ireland. MR. GUNN, in his report of his year's work, justifiably stated that the most important addition to the geology of Arran is the discovery in North Glen Sannox of a volcanic series associated with the schistose grits of that region. This set of lavas occurs in connection with volcanic agglomerate, with cherts and with dark shales or schists, like the rocks of Ballantrae in Ayrshire, and the whole is probably of Arenig age. No organisms have yet been discovered, however, either in the cherts or in the dark schists, but it is to be hoped that when the rocks come to be thoroughly searched by the fossil collectors, organisms will yet be found. Great interest attaches to the rocks in this area because they appear to be intercalated in the Highland schists, the whole forming apparently a regular and conformable succession. By this discovery the number of distinct volcanic series in Arran is increased to six.

These igneous rocks were first noticed in the month of June, but very little was then done in working out their relations to the associated schists. Specimens, however, were obtained of several varieties of the rock, and on these being shown to MESSRS. PEACH and HORNE, they at once remarked on their resemblance to the lavas of Arenig age near Ballantrae. It was not till late in the year that the survey of the district was resumed, and the area occupied by these volcanic rocks was mapped in detail After this was done MR. PEACH spent a day on the ground with MR. GUNN, seeing most of the principal sections, and he had no hesitation in identifying these rocks with those of Arenig age at Ballantrae.

As has been already pointed out, no structural line of separation can be detected between these presumably Lower Silurian rocks and the ordinary Highland schistose grits between which they are intercalated. The question is thus again raised as to how far the Silurian age of the rocks is to be extended into the Highlands. It has been impossible to find any lithological difference in the condition of the strata that are almost certainly Arenig, and the schistose grits alongside of them. They have undergone the same plication and the same degree of metamorphism, and they undoubtedly seem to form parts of one continuous and unbroken series. We are not yet in a position to solve this difficult problem. But important data are accumulating for its solution. There now seems to be every probability that both Lower Silurian and Cambrian formations enter largely into the composition of the great mass of the Highland schists.

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DEVONIAN.

Cornwall.

The field-work of the Survey among Devonian rocks last year has been confined to the County of Cornwall, where it has been carried on in the Eastern border by MR. USSHER, in the Falmouth district by MR. HILL, and around Penzance and the Land's End by MR. WILKINSON.

Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

MR. USSHER has mapped Upper, Middle, and Lower Devonian rocks in the districts of Liskeard and Looe (Sheet 348). The larger part of the area surveyed consists of Lower Devonian rocks. These make a natural junction with the Middle Devonian slates south of Liskeard, but are cut off against Upper and Middle Devonian slates with volcanic rocks on the east by a fault that runs in a south-easterly direction from the vicinity of Clicker Tor near Menheniot Station. By this dislocation and others parallel to it near Mount Edgecumbe, the Lower Devonian outcrop has been shifted to more northerly positions.

The Lower Devonian rocks are greatly disturbed by numerous contortions, thrusts, and faults, which obscure the relations of the divisions at crucial points. Their uppermost strata consist of sandstones with argillaceous slates and shales (developed south of St. Keyne), which seem to be practically unfossiliferous, and are usually of a dull greenish and grey colour. Owing to repetition by plications they exhibit a greater development on the west than on the east of the East Looe river. They are succeeded by grey slates, occasionally siliceous, and with local beds of hard grit. Thus far the Lower Devonian succession is perfectly clear, but beyond this point it is obscured by the manner in which the remaining components of the series are distributed. These embrace the Looe beds and the Polperro beds.

The fossils recorded from the Looe grits and shales are said to characterise the "Gedinnian" group of the Continent, that is to say, they indicate a lower fauna than any other found in Devonshire. The rocks with which the organisms are immediately associated include limestone in no persistent quantity, but in character, and seemingly in fossil contents, identical with beds in the Plymouth section. They comprise also interlaminated beds similar to those of Torcross and Tinsey Head. These are well shown in the coast-sections. The calcareous bands seem to occur at different horizons, but are most apparent near to or actually in contact with the red or buff shales and grits of the Looe beds. The slate series, although to a great extent identical in character with the slates which succeed the St. Keyne sandstones, is more variable, containing irregular grits, compact grits, and fossiliferous partly siliceous, irregularly cleaved grey slates, closely similar to characteristic types of the Meadfoot beds of Torquay. This similarity is so strong that were it not for their Gedinnian fossils the Looe grits and shales might well be regarded as a part of the Meadfoot beds (Lower Coblenzian) with distinctive,

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Districts of Liskeard and Looe. (Mr W. A. E. Ussher.)

locally recurrent, but impersistent lithological and palæontological characters. The classic fish-beds of Polperro lie among dark slates and hard grits, which are no doubt a part of the slate series that includes the Looe beds, but the distribution of the organisms is more general in the purple green and buff slate series of Polperro, Talland and Downderry. These variegated strata are precisely like the Dartmouth and Kingswear slates and also the slates and grits of the Revelstoke and Wembury shores. At Piskeys Cove on the Revelstoke coast MR. USSHER found remains of *Pteraspis*. Although a boundary has not been continuously drawn for the Dartmouth slates in Devonshire, their persistence and identity with the variegated slates of Polperro has been clearly proved. The Dartmouth slates of Polperro, although faulted on the north, are shown in places in unfaulted junction with the dark slates which contain traces of fish. As far as can be judged from the evidence the calcareous beds in contact with the Looe grits and shales give place to these dark slates. The latter comprise intercalated beds of hard grit or quartzite which, where present, often show intense plication. These slates form the coast-section for five miles westward from Portwrinkle, where they are faulted against Looe beds. The dislocation at first escaped notice, the red beds of the Looe series between Crafthole and Cawsand having been very naturally confounded with those of the Dartmouth slates. In the Seaton River Valley, below Hessenford, the grey slate series, with its associated grits and calcareous bands and patches of Looe beds, presents many points of resemblance to the strata above the slates of the Kingswear promontory which correspond to the Meadfoot beds of Torquay. These grey slates, which are the inland continuation of those in the East Looe coast, are bounded on the south by the Dartmouth slates of the Downderry coast, the boundary being in part at least a fault, and on the north by a mass of the Dartmouth slates which north of Hessenford extends over the ridge of Bindown to the East Looe River Valley. This mass is shifted by a fault between Bindown and Congorlan. On Bindown and above Congorlan very tough grits, containing *Pteraspis* remains, are present in association with quartzite and grey slates. On the north border of this mass, at Wringworthy, a small patch of Looe grits occurs, but with this exception there is no proof of the representation of the Looe beds in the slates on the north which come directly below the St. Keyne sandstones. In the district west of the East Looe River, the Dartmouth slates may occur in small patches. Grits resembling those above Congorlan have been detected, which may owe their position either to a prolongation of an anticlinal axis from Bindown and Congorlan, or to a fault. The slates under the St. Keyne sandstone may perhaps form the upper part of a great series, in the middle or lower part of which the Looe grits and shales and calcareous beds occur, and the dark slates, with fish remains and quartzite beds, may lie at the base of this series, directly above the Dartmouth slate group.

The chief problem of the geological structure of the Looe district

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is centred in the mass of Bindown and Congorlan. This mass is most probably an anticline. If it be regarded as a single outcrop the almost entire absence of Dartmouth slates on the west of the East Looe River will have to be accounted for by faults cutting out the whole of these slates, a view which would place the Looe beds below the Dartmouth slates, and would well accord with their presumed Gedinnian age. The evidence as to the Lower Devonian succession afforded by the Looe district alone must be confessed to be quite inconclusive. Taken in connection with the data derived from previous Lower Devonian exploration, the balance of evidence inclines MR. USSHER to the simpler view that the downward succession is as follows:— Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

Staddon grits -	St. Keyne sandstones.	
Meadfoot Beds	Beeson, Churchstow and Ringmore beds -	Grey slates, with occasional grit - Looe grits and shales.
	Torcross and Head beds.	Tinsey Grey slates, with limestone and grits.
Dartmouth slates	Revelstoke Beds -	Dark-grey slates, with interlaminated beds, and quartzite bands. - Purple, green, and buff slates, with quartzite or compact grits and arenaceous beds.

South of Pelynt the direction of dip of the schistosity is nearly always northward. The change in the prevalent southerly dip of this structure takes place along an irregular line drawn from the fault in Portnadler Bay toward Pelynt, which has no connection with any particular geological horizon. DE LA BECHE alludes to the rounding of the strike near Pelynt.

The Middle and Upper Devonian rocks in the district recently surveyed consist of slates and slaty mudstones, in which volcanic rocks occur. Their lower portions comprise argillaceous slates or slaty mudstones, often splitting prismatically, and with cleavage planes that dip generally at low angles, the bedding being frequently shown by vertically undulating, suture-like lines. Calcareous slates may be seen in the new railway line south of Liskeard Station, but there is no persistent limestone. The irregular distribution of the volcanic rocks in the tract of slate seems to be due to their lying in troughs of the higher Middle Devonian slates, and also to the fault-boundary of the Lower Devonian rocks, which cuts off the Middle and Upper Devonian series on the west, and is probably prolonged in the Middle Devonian area toward Liskeard. No boundary can be even approximately drawn between the Upper and Middle Devonian groups. Purple and green slates of the Upper group occur at Menheniot, and *Entomostraca* were obtained from them near Doddy Cross and Padderbury.

The Middle and Upper Devonian volcanic rocks consist of schalsteins and brown and greenish vesicular rocks, of which a good example is afforded by the mass on Padderbury Top. The Clicker Tor "Serpentine" is an ophitic dolerite, probably intrusive. A coarse-grained, probably intrusive basic rock occurs near Cartuther, and in the valley between that place and Menheniot.

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Districts of Liskeard and Looe. (Mr. W. A. E. Ussher.)

In the Lower Devonian area igneous rocks occur in many places but so sparingly developed and so decomposed that they cannot be indicated on the map without exaggeration. Although in places resembling sheared tuffs, their true origin remains uncertain. They are most frequently to be met with in the calcareous parts of the grey slate series associated with the Looe beds, but they also occur in the Dartmouth slates. Sheared diabases have likewise been found. The most interesting igneous rock yet encountered in the district is a highly silicified trachyte or andesite, which is quarried for road-metal on the southern slope of Bindown. It runs in an east and west direction, and is of small superficial extent. MR. TEALL has furnished the following notes regarding it:—

"[E. 3254 and 3255.] Bindown, S.S.W. of Menheniot. Grey or bluish-grey, highly quartzose rocks, traversed by veins of quartz and pyrite. Under the microscope they are seen to be highly silicified vesicular igneous rocks. Quartz has been deposited not only in the veins but also in the vesicles. The greater part of the rock is composed of quartz, but a certain amount of altered igneous material occurs as a matrix between the amygdaloids. This consists of a few rare phenocrysts of felspar in a groundmass of felspar-microlites and ill-defined interstitial matter. The nature of the original rock cannot be determined with certainty from these specimens. It appears to have been either an andesite or trachyte—most probably the latter."

Penzance District. (Mr. S. B. Wilkinson.)

In continuation of his previous mapping, MR. WILKINSON has surveyed the tract lying to the north-west and south-west of the town of Penzance. The district is almost entirely occupied by granite, but sedimentary rocks, highly altered and traversed by masses of "greenstone," rise on its eastern margin. The boundary-line between the two groups of rocks is well defined on the coast at the fishing village of Mousehole, whence it runs inland and then circles round behind Madron and Gulval. On the coast at Mousehole the sedimentary series has been very much altered. The granite is there seen to have been intruded into bluish, flaggy, fine-grained strata, which it has baked and altered almost into hornfels. Nowhere else along the inland boundary has the actual contact of this intrusive mass been observed, but the sedimentary rocks, which are cleaved red shales, all show evidence of alteration. A large band of "greenstone" stretches from Mousehole to Newlyn among the sedimentary rocks which are there changed into hard and compact hornfels. Close examination of them indicates that they have been much puckered and plicated, and that they suffered their chief metamorphism, together with the "greenstone" mass, during the period of the granite intrusion. No evidence has been obtained as to the age of these sedimentary rocks.

The best-known mass of "greenstone" in this district is that which extends from Mousehole to Newlyn. It is much used for road-metal and for the manufacture of artificial pavement. At the Penlee quarries, which give employment to a large number of men, the rock is blasted out of the face of the quarry and is afterwards broken up by the hand and by machinery. It is an exceedingly hard and tough material, and on that account

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cannot be worked with tools for building purposes. What is probably a continuation of this mass crosses the stream at Newlyn and crops out behind the church and at Mount Misery, extending in a northerly direction to Castle Horneck and Rosehill. The town of Penzance appears to have been built on a mass of this rock, which crops out at Lescudjack Hill and Coombe Quarry, extending in an easterly direction towards Gulval. In all these masses an extreme toughness of character is maintained. A large quantity of the rock is used locally for road-metal under the name of *blue elvan*. Penzance District. (Mr. S. B. Wilkinson.)

The granite of the Land's End district is seen to great advantage round the coast from Mousehole to the Land's End and thence northwards. In the interior the rock is not well exposed owing to the readiness with which it weathers and crumbles away, while round the coast, the weathering of the material along the joints gives rise to singularly artificial-looking masses. Inland the same kind of weathering occurs, but the rock appears there on the hill-tops in the form of huge mushroom-shaped bosses. Along one set of nearly horizontal or gently undulating joints the rock decays more readily than on the flat or rounded surfaces. Another set of joints which has a more or less vertical direction has not the same importance in determining the architectural aspect of the rock, but is effective in allowing it to weather into columns and obelisks.

The granite is a porphyritic rock, its most conspicuous constituents being crystals of grey felspar, which possess a beautiful pearly lustre, and are often three to four inches long and more than an inch in breadth. The ground mass through which the crystals are dispersed consists of quartz, felspar, and mica. Schorl also occurs at Castle Treneeen, where the Logan Rock stands, and which is cited by De la Beche as a good example of the occurrence of this mineral.

This beautiful granite is worked in several quarries. It is dressed on the spot, and sent away sometimes in enormous blocks. Besides the contact junction of the granite with the sedimentary rocks at Mousehole, already referred to, another is exposed further round the coast to the west at Tater-du-Point.

At Mousehole the granite penetrates and alters the sedimentary rocks into which it sends veins and tongues in every direction, and encloses portions of them. It is noticeable that the crystals of felspar (several inches long) are as large at the contact as they are in the interior of the mass. No "chilled edge" is here to be seen. On the other hand at Tater-du-Point, where the granite surrounds an inlier of "greenstone," it becomes gradually finer in grain for some six to eight yards from the contact, and at the actual junction presents a good example of the close texture so usual where masses of eruptive material have been rapidly cooled by coming against older and much colder rocks.

Veins of fine-grained granite have been observed at several places. At Mousehole fine-grained granite-veins pierce both the coarse porphyritic mass and the sedimentary rocks, while at Tater-du-Point similar veins cut across the main granite, and

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also the "greenstone." At Whitesand Bay innumerable veins of granite, very fine in texture, and varying from an inch to several feet in thickness, cut the coarse porphyritic mass in every direction.

Falmouth District. (Mr. J. B. Hill.)

Though there is reason to suspect that the rocks in the Falmouth district, long recognised to be Lower Silurian, are not by any means the only representatives of that system in this part of Cornwall, and that eventually it may prove that there are really no Devonian strata there, an account of the recent work of the Geological Survey in that district is inserted in the present section of this volume, in accordance with the order followed in previous *Reports*. Further research may justify the definite relegation of a considerable tract of ground in the south-west of the county to Silurian formations.

While the occurrence of Lower Silurian strata on the southern coast of Cornwall has been well known for so many years, the relations of these strata to the rest of the "killas" or "grauwacke" of that part of the country have never yet been ascertained. The structure of the ground is exceedingly complicated and can probably only be unravelled by patient examination with the aid of large-scale maps. This is the task which has been assigned to MR. HILL, who, from his station at Falmouth, has continued the Survey, of which some account was given in last *Summary of Progress*. He has made a perceptible advance during the past year, as will be seen from the following narrative which he has furnished:—

The field-work has been carried well into the interior. The various estuaries which diverge from Falmouth Harbour and the Helford river penetrate deep into the heart of the country, and afford more or less continuous sections of the strata. Their courses are so tortuous that the examination of them has involved the mapping of 68 miles of coast sections in addition to what was reported for 1898. These deep indentations have allowed the strata to be continuously followed without a break from the sea-coast at Falmouth to practically midway across the breadth of Cornwall. Advantage has also been taken of the numerous cuttings along the line of the Great Western Railway. All these natural and artificial sections have been mapped in detail, and have been of considerable service in the working-out of the stratigraphy of the district, since generally over the surface of the interior the rocks are only to be seen in isolated exposures and usually in an advanced state of decomposition.

It was mentioned in last *Summary* that, in the absence of palæontological data MR. HILL had separated the slates of the district lithologically into the following divisions *:—

1. Veryan beds.
2. Portscatho slates.
3. Variegated (Falmouth) slates.
4. Mylor series.

* *Summary of Progress* for 1898, p. 97.

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Falmouth District. (Mr. J. B. Hill.)

These groups succeed one another in the order here given from east to west, and their persistence over wide areas as distinct stratigraphical horizons has been confirmed by the work of last year. The eastward extensions of the Portscatho slates in Veryan Bay were coloured by De la Beche as Lower Silurian, and the same strata, after striking into Gerrans Bay, make their appearance again south of the Helford River. The part of the district to the south of Falmouth has now been examined, and the results of the work will here be briefly stated.

In order to determine the relations between the Portscatho slates (No. 2) and the strata south of Helford River the coast-section was examined in detail between Falmouth Bay and the Nare Point. From Maen Porth, where the Variegated Slates (No. 3) are last seen, the coast, as far as the Helford River, presents an uninterrupted section of the blue slates and fine sandy beds of the Portscatho slate series in their normal condition. South of the Helford River they are well exposed as far as St. Anthony Creek. As they are followed southward, however, they have suffered more severely from the stresses which have induced the folding and cleavage of the rocks. At Dennis Head the structures set up by these movements have been carried a step further. The strata have been, as it were, subjected to mylonisation (or crushing) of a coarse type, insomuch that they have been reduced to a mass of coarse lenticular patches of rock, the lenticles being several feet, in some cases yards, across, and the whole presenting the character of a gigantic breccia. These lenticles, when they have been torn from quartzose beds, resemble huge boulders; in other places the apex of a folded limb has been detached and isolated from the parent mass. This extremely coarse type of brecciated structure is more or less continuous along the coast as far as Porthalla, where the northern edge of the Lizard "complex" appears.

Between Dennis Head and the Nare Point a conglomerate is interbedded with blue slates. Near the Nare Head a quartzite appears, and further south, nearer Porthalla, a small limestone band. The limestone and quartzite, as well as the conglomerate, are found associated with the blue slates.

The conglomerate was described by De la Beche,* who recognised in it fragments of hornblende-slate in addition to the material supplied from local sources. It is well seen on the shore east of Men-aver Point where it has an outcrop of nearly a third of a mile. Still farther east, at the Nare Point, conglomerate is again exposed for a few yards. As the strata are highly folded it is probable that the successive outcrops are parts of the same mass. Before the main body of the conglomerate comes on, thin seams of fine conglomerate may be observed to be intercalated in the slates. These seams vary from six inches to a foot in thickness. Commencing next the slates as sandstone, they rapidly become coarser, occasionally including fragments three or four inches across. The fragments are made up of black slate

* *Report on the Geology of Devon and Cornwall*, 1839, p. 94.

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Falmouth District. (Mr. J. B. Hill.)

and greyish green slate, rounded and sub-angular, together with angular pieces of white quartz. This part of the rock is generally fine-grained. The coarse conglomerate begins with a fringe of similar material, which also forms the matrix of the coarse mass. The larger boulders are made up of slate, quartzite, and vein-quartz. Many of the quartzite-blocks are of huge size; the smaller boulders of this material are generally well-rounded, as are also many of the fragments of white quartz. In addition to these fragments, which have been derived from rocks in the immediate neighbourhood, boulders of foreign material are also present, consisting of granitic and felsitic rocks, some of which are foliated; quartz-felsite and green schistose fragments, some of which are probably referable to the hornblende schists of the Porthalla district to the southward, while granitic and felsitic fragments may have been derived from the older rocks of the Lizard; at least they do not resemble the granite and associated rocks that lie to the north of this part of Cornwall. These far-derived materials are generally in a highly decomposed condition; they have also suffered brecciation from the stresses to which the Conglomerate has been subjected in common with the rest of the rocks of the district. Amongst the fragments of green rocks in the Conglomerate, one which was very serpentinous but highly fissile, unfortunately could not be extracted from the rock. Whether it should be associated with the Lizard serpentines, must remain doubtful. BOASE, indeed, has stated that fragments of serpentine and diallage-rock occur. DE LA BECHE observed hornblende slate, but could not detect serpentine or diallage-rock. Since the time of DE LA BECHE'S survey the existence even of pieces of the hornblende-slate has been doubted, no subsequent observer having detected it. MR. HILL'S observations tend to confirm DE LA BECHE'S statement. If the fragments of foliated granite have, as is probable, been derived from the Lizard district, serpentine may perhaps yet be found included in it. It must be borne in mind, however, that the granite and other igneous fragments, supposed to have been derived from that district, are generally much decomposed, so that the chances of so soft a rock as serpentine surviving attrition during transport might not be great. Although better able to resist severe movements of the terrestrial crust than the slaty rocks among which it lies, the Conglomerate has undoubtedly experienced similar stresses. Its upper layers have yielded to the movements as completely as the slates on either side of it. Moreover it is traversed by planes along which shearing has taken place, so that its constituent boulders have sometimes been broken across. Thin quartz-veins occasionally traverse both boulders and matrix. The quartzite boulders are sometimes almost welded into the gritty parts of the Conglomerate. A mica-trap dyke rises in the Conglomerate, in which it is no doubt intrusive, although its junctions with that rock are not seen. No fragments of it occur in the Conglomerate. The mica-trap is of the normal type of the dykes which in this district cut the Portscatho slates.

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Falmouth District. (Mr. J. B. Hill.)

The quartzite is first seen on the south side of Nare Point, but on account of the coarse brecciated structure that has been previously described as occurring in this neighbourhood, it cannot be continuously followed. It occurs here as a lenticle about 10 feet long and 5 or 6 feet wide. A little further south, between Nare Point and Nare Head, the quartzite seen a little inland above the cliff probably represents the parent mass from which this large lenticle has been isolated. It is a grey compact rock which has suffered a great deal from the brecciation of the district. Its interstices are filled with vein-quartz, consequently it is a mixture of quartzite and secondary-quartz. Except that it is more brecciated, it is similar in character to the quartzite of Carne in Gerrans Bay. The thin limestone seen near Porthalla also resembles the limestone at Gidley Well in Gerrans Bay.

Gerrans Bay. (Mr. Hill.)

Besides the quartzite of Carne and the limestone of Gidley Well, the Veryan series of the Gerrans Bay district also contains a conglomerate, and is thus brought still further into relation with the strata between Dennis Head and Nare Point south of the Helford River. Indeed, the evidence furnished by a study of the two sections is ample for the correlation of the rocks in the two areas. De la Beche clearly recognised the probability of their identity,* although the Veryan beds were coloured on his map as Lower Silurian, while what must be regarded as their equivalents south of the Helford River were coloured as Devonian. As the Veryan beds have been determined by palæontological evidence to be Lower Silurian, it is clear that strata of Lower Silurian age extend still further to the south-west, and that they form the northern boundary of the Lizard mass of eruptive rocks.

The positions of the four groups of strata enumerated in the table on p. 88 were given last year mainly as they appear on or near the coast line. But as these strata have since been traced well into the interior of the county, a better idea of their geological range can now be afforded.

The Veryan group, as we have already seen, after being lost in Gerrans Bay, reappears on the Meneage Peninsula to the south-west. It is then succeeded further west by the Portscatho group, which is well exposed along the coast line from Gerrans Bay to the Zoze Point. On the west side of the Carrick Roads, the Portscatho slates occupy the country between Falmouth Bay and the Helford River, from which they continue in a south-westerly course. From Pendennis Point they have an average north and south strike as far as Truro, and occupy the broad tract of country between that place and Gerrans Bay. The Mylor series (No. 4) covers an area of perhaps equal extent west of a north and south line between Truro and Falmouth. The Variegated Slates (No. 3), which lie between the Portscatho slates and the Mylor series, have been ascertained by the recent mapping, as far as this district is concerned, to be of much smaller extent than the two divisions

* *Op. cit.*, p. 95.

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Gerrans Bay. (Mr. Hill.)

which it divides. Some further particulars may be given in addition to what was stated last year in reference to the several groups.

In respect to the Portscatho slates, indeed, little has now to be added to the former description. They are almost continuously exposed along the whole line of coast from Gerrans Bay to the head of Helford River, and the greater part of the estuaries that strike inland from the Carrick Roads traverse this series of strata, so that, as it can be followed in continuous coast-sections across the strike from the mouth of Falmouth Harbour to Truro and Tresilian, unusual facilities are afforded for its detailed examination.

The Variegated Slates which form a well-marked belt at Falmouth cannot be so continuously traced. Between Falmouth and Truro they appear in lenticular strips, either as infolds within the Portscatho series or else as partitions between the Portscatho and Mylor series, while occasionally they may be seen as infolds within the area of the Mylor series. The axes of the isoclinal folds into which all the groups of strata have been thrown, do not correspond with the general strike of the stratigraphical zones but cross it rather obliquely, so that the mapping brings out several more or less parallel lenticular masses of the Variegated Series along a zone oblique to their longer axes, the several repetitions being due to isoclinal folds. These infolds are never found very far from the general boundary of the two adjoining series, except near Ruan Lamhorne, where two such patches occur within the Portscatho series, but indicating probably the upward limit of the Portscatho series at that place. The ground southwards from Falmouth affords similar evidence. The large belts at Falmouth and Maen Porth, apparently, "nose out," and the section along the Helford River which crosses the strike shows numerous zones of this series interfolded with the Portscatho slates. So close are these intercalations that in many cases it is quite impossible to separate the stratigraphical divisions on the map.

It was pointed ont in last *Summary* that the Variegated Slates of Falmouth are more arenaceous than the series at St. Mawes, and as these are carried still farther to the south-west, they are found to be mainly arenaceous, almost to the total exclusion of argillaceous material, so that at Helford River they are represented almost entirely by buff sandy beds. Hence the alternations in colour from the green argillaceous to the buff sandy type are also lost, and consequently, instead of being variegated they are here of a uniform buff tint. Within this series of strata, both at Falmouth and at St. Mawes, narrow zones of sharply-contrasted purple and green slates have been observed, likewise to the north of St. Mawes, between Mesack Point and Turnaware Point, where rocks of this character are strongly developed in the Variegated series.

The Mylor series of finely-striped slates has been found to present a remarkable brecciated structure, to which brief allusion was made last year. So uniform was this character of the series

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over large areas, that this particular structure was supposed to be due to original conditions of deposit, rather than to secondary processes of deformation. The field-work of last season, however, has revealed that the brecciation is not so common as was believed from the mapping of the strata between Falmouth and Restrongult Point. The structure in question seems to be more or less confined to the latter locality, the outcrops further west and north being practically free from it. It is probably the result of the stresses to which the beds have been subjected. Its extent may be gathered from the fact that in some places it may be continuously followed across the strike for over half a mile, the strata being made up of a mass of fragments from the size of peas up to 5 or 6 inches in length, enveloped in a slaty matrix and with their flat sides lying in more or less parallel planes. These breccias clearly consist of the same material as the non-brecciated part of the same group, which is composed of inter-laminations of pale and dark argillaceous, occasionally pale siliceous material. The fragments are, as a rule, angular, but some are well rounded. Although direct evidence of their origin is not often forthcoming, yet, occasionally, stages may be detected in the process of manufacture which if carried a step further would have resulted in the production of isolated fragments. Besides having been thrown into numerous isoclinal folds, these strata throughout their whole material have been affected. The Mylor series, from the varying nature of its interlaminations and the corresponding variations in their ability to resist crushing, appears to have been unable to overcome the main strains without this process of brecciation. Still, for the most part, this structure is evidently rare; it occurs only in the neighbourhood of faults, and is evidently the last stage after the folding. The separation of the fragments has been due to the limbs of folds being isolated by the movements, which have produced a structure somewhat similar to the coarser lenticular structure in the section between Falmouth Bay and the Nare Point. There has been a combination of minute over-folds and thrusts. Instances may occasionally be seen where the disruption of the folds is not quite complete, and where the almost isolated folded limb precisely resembles the separated fragments. The phenomenon appears to be related to that described by Mr. Lamplugh in his paper "On the Crush Conglomerates of the Isle of Man." In the Cornish examples, however, there can be no doubt that the alternating materials of which the strata are made up has been a potent factor in this type of deformation.

Gerrans Bay. (Mr. Hill.)

The brecciated structure now described as so prominent a feature in the Mylor series is not confined thereto. A similar structure on a large scale may be seen south of Helford River, even in the Mylor series itself at a distance from the brecciated areas. Feebly brecciated zones are met with in the neighbourhood of faults. Minor zones of brecciated material can likewise be seen in the Portscatho series, generally in thin bands near a fault where small angular fragments of slate may be found enclosed in a matrix of similar material.

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Gerrans Bay. (Mr. Hill.)

In Gerrans Bay in one of these bands of brecciated dark slate a crinoid stem was seen to be apparently unbroken. It would be almost impossible to separate this band from similar strata where the brecciated origin is clear. The rock seems to have been able to undergo considerable deformation as a whole while small portions were unaffected. The isolation of the fragments has sometimes been produced without folding; instead of faulting succeeding the folding, the stresses have resulted in the direct formation of movement-planes, which have isolated the fragments from the main mass.

The igneous rocks of the Falmouth districts, besides the granite and the quartz-porphyry dykes, are of the types consisting of greenstones and mica-traps. The former, many of which are schistose, are confined to the Mylor series, while the latter are found in the other stratigraphical divisions. These are especially numerous along the Fal actions of the Portscatho series.

The margin of the granite being everywhere obscured, the ground has proved highly unsatisfactory for the study of the effects of contact-metamorphism on the slates. Although the boundary of the eruptive rock has been followed for nine miles, the actual junction of the granite and slates has only been observed at one place. Besides the knotted structure, referred to last year, muscovite and biotite have also been developed in the slates. The mica increases in abundance towards the granite and has been observed as far as half-a-mile away from the line of contact. It occurs in minute scales but in considerable quantity, and both micas in about equal amount, but white mica is more confined to the immediate neighbourhood of the granite, whereas black mica occurs equally over the whole aureole where a micaceous constituent is present. The knotted slates have sometimes been observed at a distance of a mile and a-half from the nearest visible granite.

As pointed out in previous Reports, the structures of the stratified formations in the south of Cornwall are identical with the structures of crystalline schists. In the Falmouth district, so far as yet examined, true slates have not been met with. The strata have been thrown into a series of isoclinal folds accompanied by small faults. With these folds and faults minor structures have been set up until the whole rock has often become a mass of minute folds and thrusts with their accompanying strain-slip cleavages. These processes, as we have seen, have been carried so far that "crush-conglomerates" have been produced on a large scale. It is evident from a study of this district that had the rocks been subjected to these stresses at a greater depth and below the zone of fracture where they would not have been so free to move, they would have been converted into true schists. They possess now every structure of schists, but the mineralization has been wanting.

The visible dip of the rocks is of no value, except as registering the inclination of the limbs of folds. As an illustration of this fact, it may be pointed out that although the strata have a steady

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dip to the south-east between Falmouth and Truro, and we are apparently crossing the strike from the coast to the heart of the county, yet instead of getting deeper in the stratigraphical series we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds. Gerrans Bay (Mr. Hill.)

Age of the Stratified Rocks in the Falmouth District.—The limestones and quartzites of the Veryan Series contain fossils which determine these beds to be Lower Silurian, and they were recognised as such by DE LA BECHE, and coloured accordingly in his map. The Conglomerate already alluded to as occurring at Nare Head in Gerrans Bay, and at a headland bearing the same name south of the Helford River, contains boulders and pebbles of quartzite and not improbably marks a break between the Upper and Lower Silurian formations. Although the succession from the Veryan series to the Mylor series is apparently a descending succession, the true position is probably the reverse, and the Portscatho, Falmouth, and Mylor series may be Upper Silurian. At present no palæontological evidence is available to settle the stratigraphical position of these strata, which in the meantime can only be provisionally determined by their relations to the Lower Silurian rocks. If this interpretation should prove to be correct, the Devonian system is not represented in this part of Cornwall.

OLD RED SANDSTONE.

Ross-shire and Inverness-shire.

A few additional particulars have been collected during the past year regarding the lower division of the Old Red Sandstone of the basin of the Moray Firth. It has long been known that detached outliers of the formation are scattered over the schist-country of Sutherland and Ross. A number of previously unobserved outliers of this nature have been met with in the progress of the Geological Survey through these counties. Two of them which were detected by MR. GUNN to the north-east of Loch Luichart in the east of Ross-shire* have now been mapped by MR. PEACH. They consist of breccia which caps the two mountains Beinn a Bhric and Beinn nan Cabag. In placing the details of their structure on the maps MR. PEACH has noticed further evidence of the exceedingly uneven surface of schists on which these breccias and conglomerates were deposited. In particular the remarkable augen-gneiss which forms so conspicuous a feature in the geological structure of that district rose as a ridge above the rest of the crystalline rocks in the waters of the Old Red Sandstone basin. Loch Luichart. (Mr. B. N Peach.)

Further progress was made by MR. HORNE in mapping the Old Red Sandstone in the Valley of the Nairn to the East of Strath Nairn Inverness-shire. (Mr. Horne.)

* Annual Report of Geological Survey for 1896, p. 53.

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Inverness. In tracing its boundary along the west side of the valley he observed that the basement conglomerate contains pieces of the surrounding granulites and biotite-gneisses, and also blocks of porphyrite and felsite.

Beauly District. (Mr. Hinxman.)

In the same basin a further tract of Old Red Sandstone has been mapped by Mr. Hinxman from his station at Beauly. He has traced the western limits of the formation northwards to the Conon at Torrachilty. Above Clachuile Inn the river flows for some distance over a series of gently-inclined grey micaceous shales and flagstones, the general direction of dip being east-south-east. At Newton, a short distance below the rapids, the beds roll over towards the west, and rest at much higher angles. Immediately below the fall the shales are intercalated with and pass up into a well-bedded conglomerate, composed of rounded stones of moderate size, and altogether different from the coarse tumultuous breccia of Glen Orrin and the Beauly river.

The junction between the conglomerate and the Moine schists at the fall is a faulted one, and is accompanied by a considerable amount of disturbance and brecciation in the schists. The line of this fault can be followed through the woods of Coille Mhor to Glen Orrin, where it leaves the conglomerate, and passing into the muscovite-biotite-gneiss has determined the northerly course of the Orrin above Strathan for a short distance.

The outcrop of the grey shales is marked by a line of sulphurous wells of varying strength. Some of these springs rise in the bed of the river, and are only seen when the stream is at a low level. Others appear at Muirton Mains, Coul of Fairburn, and in the river Orrin at Balno. There is also a well-known spring of this nature just outside the village of Beauly, indicating the presence of the shales at this point beneath the thick covering of recent marine alluvium.

Lorne, Argyllshire.

In the *Summary of Progress* for 1897, and in that for 1898 accounts have been given of the interesting discovery of remains of fishes and other organisms in the sedimentary strata associated with the volcanic series of Lorne. The occurrence of *Cephalaspis* definitely proved these strata to belong to the Lower Old Red Sandstone. During the past year further information has been obtained regarding the fauna that was contemporaneous with the *Cephalaspis* in the ancient water-basin of Lorne. Remains of Ostracod crustaceans have been detected, and though their state of preservation is not as perfect as could be wished, their forms are at least generically recognizable. Possibly some layer of stone may yet be met with in which not only these, but other organisms have been more perfectly preserved. Palæontological notes on this subject will be found on p. 186.

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Oban and Kilmelfort District. (Mr. R. G. Symes.)

In the Lorne basin of the Lower Old Red Sandstone further field-work by Mr. R. G. Symes has added to our knowledge of the extension of the sedimentary portion of the formation in that region, and at the same time has brought to light fresh points of interest in connection with the remarkable volcanic phenomena of this basin. Thus he has detected several previously unrecorded outliers of the conglomerate in the neighbourhood of Kilmelfort. One of these, of considerable size, lies a mile and a-half east of Kilmelfort Hotel, and to the east of Loch a' Mhinn. The material of which it consists is entirely different from that of any other conglomerate in the Oban district. It is made up at its base of large blocks, chiefly of porphyrite, epidiorite, limestone, schists, slates, and some quartzites, with but little matrix. At first it was supposed to be an agglomerate from the angularity of its constituents, but when the ground was more fully examined the upper portion of the mass was found to be similar to other parts of the Old Red conglomerate. North-east of Loch nan Ban, where the conglomerate rests on a floor of felsite which in places is highly porphyritic, the greater proportion of its blocks consists of that rock. On the west side of the exposure the lower part of the mass lies on thick limestones, phyllites, and epidiorites. Occasional pebbles of vein-quartz are met with in the higher layers, but bedding is not apparent, nor any trace of intercalated sandstones or shales. The greater number of the blocks in this rock near Loch a' Mhinn consists of a pink felspathic porphyrite. The conglomerate is there cut by a pink felspathic porphyritic dyke similar to those found elsewhere, rising through the Lower Old Red Sandstones and their associated andesites. These dykes trend from north-north-east to south-south-west. The strata exposed in this outlier must in some places be as much as 400 feet. The conglomerate here has no andesite capping, nor have andesite blocks been noted among its constituents.

North-east from Loch Losgain Beg another outlier of conglomerate extends from Loch a' Mhinn westward, and is found adhering to the quartzites and epidiorites on the east side of Barr Kilmhealaird. It is composed almost entirely of decomposed felsite-blocks, set in a matrix of comminuted material of the same kind. On the southern shore of Loch a' Mhinn a third small outlier has the same composition as that last mentioned, both of them being totally different in their ingredients from the mass east of Loch a' Mhinn, which is only distant a couple of hundred yards. From the considerable area covered by the conglomerate to the south and east of Loch Fear, near Kilmelfort, the rock might be supposed to be well developed there, but as it lies horizontally, and has had its protecting cover of andesitic lavas removed by denudation, its thickness in some places does not exceed a few feet.

At the foot of the waterfall from Loch Fear the basement-beds of the Lower Old Red Sandstone consist of thin purple shales lying below the conglomerate and resting on siliceous schists and limestones. Such an intercalation is most unusual throughout

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Oban and Kilmelfort District. (Mr. R. G. Symes.)

the Oban district. It may be remarked in passing that under the shallow waters of Loch Fear a beautiful ice-polished surface of the conglomerate may be seen wherein, as in a kind of mosaic pavement, the pebbles of quartzite, pink porphyrites, vein-quartz, and epidiorite are displayed. The irregular floor on which the conglomerate was laid down is well seen to the west and north of Loch Losgain Beg, a mile east of Kilmelfort, while on the western slopes of Barr Kilmhealaird, the way in which the conglomerate passes down into cracks in the schists and epidiorites is conspicuous. These prolongations of the conglomeratic material downward might here and there be mistaken for actual intercalations of the conglomerate in the schistose series underneath. This series here consists of schists (phyllites) with calcareous bands, quartzite, epidiorite, porphyrite, and felsite with flow-structure. All these rocks are represented among the pebbles in the conglomerate, which are mostly sub-angular, and never quite well rounded. Here, as usual, they are local in origin. Near the outcrop of the porphyrite, blocks of that rock more than two feet long are found in the conglomerate. No fragments of andesite like that of the true lavas have been observed in this exposure.

The general local derivation of the materials in the conglomerates is well shown all over the Kilmelfort district. Thus on the hill side above Loch nam Ban, two miles east of the village, the rock is so much made up of the pink felsite upon which it rests that, but for some rounded pebbles of quartz that stand out on weathered surfaces, it might easily be mistaken for an igneous mass. The same close relation to the underlying material may be observed further to the east, in the stream which joins the Duchara Burn, near Lagalochan. At both places the compact conglomerate is the highest bed exposed in the section east of Loch a' Mhinn. About a quarter of a mile above the road, crossing the stream already alluded to, the conglomerate has been derived from the white decomposing felsite on which it rests, while nearer the road it is fine-grained and hard, resembling the conglomerate seen above Loch nam Ban. Along this stream a large north-north-east and south-south-west fault runs, with a downthrow to the east, whereby the compact conglomerate on the top of the series is thrown down against the epidiorites on the west side of the stream.

A further illustration of the uneven and cleft surface on which the Old Red conglomerates of this district were deposited may be observed on the shore, about a mile and three-quarters to the south-west of Kilmelfort close to the old Fort, and a little west of a porphyrite sill there exposed. The schists are here traversed along their planes of schistosity by a series of cracks now filled with a brecciated conglomerate similar to that which occurs on the hill side to the north of Loch Losgain Beg above mentioned. Although the overlying conglomerate has disappeared there can hardly be any doubt that these veins of its material belong to it, and represent the local base of the Old Red Sandstone, of which so large a part has been removed from this area by denudation.

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North of Loch Tralaig, about three miles north of Kilmelfort, and to the east and west of Innie farm-house, thin beds of conglomerate appear from under the andesite. Again, to the north-west of Corrielorne, beds of conglomerate form the floor on which the andesites rest, while east of Tralaig, and north-east from the farm-house of Druimnashallag some red and purple shales intervene between the lavas and the epidiorites. These are the only exposures of the sedimentary representatives of the Lower Old Red Sandstone to be met with in that part of the district for a distance of six miles from east to west. In the Pass of Melfort, at the sharp angle in the road, some red, horizontally-stratified deposits, with black layers, about four feet thick, may possibly fill an enormous sand-crack. MR. TEALL found them, on examination of specimens, to be composed of disintegrated andesite. Oban and Kilmelfort District. (Mr. R. G. Symes.)

To the north of Loch Avich, seven miles east of Kilmelfort, and west of Drissaig, the conglomerate dips to the east, underneath the lavas, and attains some thickness. It here differs from the conglomerates previously enumerated inasmuch as its chief constituents are fragments of andesite and epidiorite. The surface of the blocks in this mass has been well polished by ice, the direction of striation being east and west. This outcrop of fragmentary material may belong to a somewhat later part of the series than those conglomerates which have derived their constituents entirely from the schist-platform below; at least, it was not deposited until the eruption of the andesites had begun, whereas in the other examples referred to, no fragments of these lavas have been as yet detected.

A large part of the southern outcrop of the andesitic lavas of the Lorne region has been mapped during the past year. The margin of this volcanic area presents an irregular east and west line of escarpments rising above talus-slopes. The only gap or road through this area in a north and south direction is that of the pass of Melfort, formed by the River Oude, which has cut its way through the thick mass of lavas. At the southern limit of the andesites exposed in the road in the Pass of Melfort, close to the avenue gate to Melfort House, the volcanic sheets are seen to rest upon phyllites and epidiorites, with no intervening layer of sedimentary deposits. No outliers of the andesites have been noted to the south of Kilmelfort, or beyond the southern edge of the volcanic area.

When the mapping of the andesite-flows was in progress in the neighbourhood of Loch Tralaig, it was difficult to decide whether a large east and west fault runs along the southern shore of the lake, throwing down the volcanic rocks on the south against phyllites and epidiorites on the north, or whether denudation had removed all the lavas on the west side of the loch, so as to expose the schists, quartzites, epidiorites, and intrusive dykes. The section of the lavas to be seen south from the lake shows them to be almost horizontal. No trace could be found here of tuffs like those north and south of Loch Etive, nor are there any acid lavas such as have been found near Taynuilt and Airds Bay, in the north-east portion of the Oban district.

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Oban and Kilmelfort District. (Mr. R. G. Symes.)

The greatest thickness of the entire series of andesitic lava-sheets between Tralaig and Kilmelfort is possibly not more than 500 feet. It has now been ascertained that the greatest development of these lavas occurs between Lochs Etive and Creran, and that the thickness of the sheets gradually lessens towards the south. About half a mile south-east of the shepherd's house of Maolachy, four miles east of Kilmelfort, an irregular mass of intrusive acid igneous rock in all probability belongs to a neck or volcanic vent. It is elongated in an east and west direction, and is about a quarter of a mile long and about half as broad. MR. PEACH, who twice visited the ground, has furnished the following notes on the field relations of this mass:—"It consists of an acid igneous rock, probably a very acid andesite, or perhaps a rhyolite, in which evidence of flow while the rock was in a very viscid state is everywhere conspicuous, the whole rock being now quite platy and its layers so highly crumpled as to simulate a puckered schist. The planes which separate these plates conform in a remarkable manner with the outward edges of the mass, and are either more or less vertical or dip inwards at high angles. Often near the edge the mass includes numerous blocks of the surrounding dark slates or epidiorite sills. It also contains broken-off portions of material similar to itself, which show flow-structure in a marked degree. So numerous are these fragments in some places that the rock looks like a brecciated conglomerate or agglomerate. The nature and the source of this breccia are well exhibited in the stream which skirts its north-western limit, where its contact with the sedimentary rocks is best exposed. Here the line of contact with the dark schists and limestones can be followed for about 200 yards. The rocks are much shattered, and their junction with the igneous mass is somewhat irregular, but the latter rock is seen to have flowed upward, conforming to the uneven surface, and catching up innumerable fragments of the black slates and limestones, as well as bits of its own chilled outer layers, and involving them in the still flowing viscous rock. This is in all probability a neck or vent which may have supplied the material of the more acid lavas and tuffs of the volcanic platform of Lower Old Red Sandstone age in Lorne."

Near Loch nan Losgain Beg several other masses of a similar flow-breccia are to be seen. Some parts of these contain more broken up fragments than matrix. But that they are truly of eruptive origin can be shown in many cases where they act as dykes or sills, and cut both the rocks of sedimentary origin and the epidiorite sills. They are in turn cut by the tertiary basalt-dykes. They are all probably of the age of the Lower Old Red Sandstone, and belong to the later phase of vulcanicity in the history of the lavas of Lorne. They are usually associated with "porphyrite" dykes, and may be regarded as not improbably continuations of such dykes as have continued to flow after having cooled to a very viscid condition and partially solidified. Flow-structure is also exhibited at the edge of some of the porphyrite sills.

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County Waterford.

Bunmahon Distr.ct. (Mr. J. R. Kilroe.)

While the revision of the Silurian areas has been in progress it has occasionally been necessary to carry the investigation into the surrounding tracts of other rocks. This prolongation has been especially imperative in the south of the County of Waterford on account of the complexity of the coast-sections and the accumulating evidence that much of the igneous material there developed, though enclosed within the area of the Silurian rocks, belongs to a later than the Silurian period.

The age of the red sandstone, grits, and conglomerates, exposed on the coast at Bunmahon, has long been in dispute. The strong resemblance of these strata to the Old Red Sandstone of the neighbouring Comeragh region induced the original surveyors to consider them of corresponding age, and they were so represented upon the first edition of the one-inch sheet (No. 178), published in 1857. Their apparent interstratification with supposed volcanic tuffs and lavas of Silurian age, subsequently led to the abandonment of this view, and to the relegation of these red rocks to the Lower Silurian group, under which colour they appear on the edition of the map issued in 1863, which has not since been changed. A more recent examination of the district led the present Director-General of the Survey to question the correctness of the alteration and to express the opinion that the original view would not improbably prove to be correct. Believing that the igneous rocks to the east had been truly assigned to a Lower Silurian date, he thought it probable that a second set of igneous rocks existed which could not be older than the Old Red Sandstone.* Still more recently Mr. Cowper Reed has concurred in the original view. He mentions the superposition of the red rocks upon denuded igneous masses which were supposed by the authors of the revised edition of the map to be interbedded and contemporaneous. He bases his opinion as to the age and position of the conglomerates upon their relation to the igneous rocks, conjointly with their having undergone great disturbance and dislocation after Old Red Sandstone times. As the basal conglomerates at Ballydowane Bay—the principal place in which the red rocks are to be seen—contain pebbles of igneous material identical in character with that which forms the greater part of the perplexing intrusion-breccia at Bunmahon Head, it is not difficult to account for these differences of opinion. Accordingly Mr. Kilroe has devoted some time to a careful examination of the perplexing evidence, and he has supplied some notes of the results which he has so far obtained.

Occurring in five small isolated tracts, and usually showing high dips or set on end, the red rocks seem to lie in deep synclinal basins, the longer axes of which correspond with the trend of the neighbouring igneous bands, with the general

* *Ancient Volcanoes of Britain*, vol. i., p. 251

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Bunmahon District. (Mr. Kilroe.)

direction of cleavage, and with the strike of the highly inclined Old Red Sandstone near Dungarvan. Though much faulted the strata present a clear succession at several points along the coast.

An important section on the cliff in the middle of Ballydowane Bay shows the following succession in ascending order, viz. :—

(*a.*) Basal deposit, several feet thick, consisting wholly of igneous detritus—green and grey felsites and some basic (?) rocks ; pebbles for the most part well-rounded. The beds rest at about 80° against igneous rocks similar in character to most of the pebbles, and weathering, specially near the junction, into a conglomerate-like mass, so that the line of demarcation between the two rocks is not distinctly traceable. No true tuffs or other truly volcanic rocks have been recognised either in the material of or near the basal deposit.

(*b.*) Red argillaceous grit, with massive bed of grey grit.

(*c.*) Conglomerate, consisting chiefly of white quartz-pebbles embedded in a red sandy matrix.

On the shore at the west end of the bay the adjoining igneous rocks are to be seen invading green grits and epidotic and serpentinous fossil-bearing Silurian limestone. On the east side of the bay the argillaceous grit, which as usual passes up into quartz-conglomerate, rests directly upon igneous rock, which, at this point, also penetrates green calcareous grit. The boundary here seems to be a thrust-plane, and though the hade (38°) corresponds closely with the dip of the immediately over-lying strata (38° to 45°), the dislocation may have cut out the conglomerate which elsewhere occurs at the base of the series, and appears at the other side of the same synclinal basin. A vertical fault, almost parallel to the break just mentioned, cuts out the basal deposit at one point, but leaves a small thickness of it resting against igneous rocks, where it is seen to consist, as at other points, of fairly well-rounded igneous materials.

Close to Bunmahon Head the red grits are faulted against green felsites, and pass up into quartz-conglomerate. At the ore-yard and site of engine-house, Knockmahon, quartz-conglomerate overlies red grits, which commence with a fine breccia of igneous detritus, resting upon and against green felsite, which in the immediate vicinity penetrates Silurian fossil-bearing calcareous grit.

The section of undoubted Old Red Sandstone, near Ballyvoyle Head, presents a series of strata closely resembling those now described. Red argillaceous grit is there seen to intervene between quartz-conglomerate and the base of the series; while local blocks scattered on the beach, and probably detached from the basal beds at present concealed, show that these beds consist of conglomerate formed of igneous materials similar to those at the base of the Bunmahon series. This fact is all the more significant since the Old Red Sandstone floor in the Ballyvoyle coast section is formed of dark-grey and black slate, penetrated by a few felsite dykes. The Bunmahon conglomerates may therefore, with little hesitation, be regarded as belonging to the same series as the

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strata near Dungarvan, which are known to be of Upper Old Red Sandstone age. The igneous rocks which preceded the red rocks at the one place also preceded those at the other; and as these igneous rocks have invaded Lower Silurian strata, while fragments of them abound in the overlying conglomerates, their intrusion must date between the Lower Silurian and Upper Old Red Sandstone epochs. Bunmahon District. (Mr. Kilroe.)

But not only do the red strata contain abundant detritus of eruptive rocks, they have themselves been invaded by some of these rocks. At the southern end of the little promontory at Bunmahon Head they are penetrated by an intrusion which is seen to cross obliquely some twenty feet of quartz-conglomerate and red grit, within a distance of about 100 yards. Both igneous and sedimentary rocks at the junction are crushed, but not to such an extent as to obliterate the evidence of intrusion. The red strata, moreover, near the junction contain injections of a green igneous rock; and the adjoining igneous mass, includes fragments which resemble, if they are not, those of red grit. Like some of the rocks further east, to which reference has already been made, this mass is composed of green felsites, and perhaps andesites, in rounded lumps, which are embedded in and cut up by, a more basic material. The rock is now a coarse aggregate, which might readily be taken for a volcanic agglomerate.

A close resemblance is noticeable between this basic rock at Bunmahon Head and another which contains numerous quartz-pebbles near Mount-Kennedy, eight miles to the north-west. This highly vesicular rock afforded material to the Old Red strata overlying it. Pebbles of similar material were observed in local blocks taken from the base of the Old Red Sandstone at Ballyvoyle Bridge.

CARBONIFEROUS.

The field-work of the Survey among Carboniferous rocks during the past year has lain in the coal-fields of North Staffordshire and South Wales. In each of these regions satisfactory progress has been made in mapping not only the coal-fields, but also the surrounding areas, which, though largely covered by younger formations, must be surveyed in order to allow of the publication of the various one-inch sheets in which the coal-bearing tracts are represented.

North Staffordshire

The revision of the North Staffordshire coal-field and surrounding country has been continued under the supervision of Mr. Fox Strangways by Messrs. Barrow, Gibson, Pocock, and Wedd. Mr. Fox Strangways has himself been mainly engaged upon the Jurassic tracts that lie to the east of the Rushton Spencer. (Mr. Fox Strangways

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Rushton Spencer. (Mr. Fox Strangways.)

Leicester coal-field, his share in the North Staffordshire having been mainly that of taking general charge of the mapping by his colleagues. He reports that at Rushton Spencer, five miles to the north-west of Leek, a group of sandstones and shales which is there developed, has been considered to represent the Permian rocks of that district,* but that the strata precisely resemble the sandstone and shales which further south have been mapped as part of the Carboniferous system. He thinks that there can be little doubt that they belong to the "Yoredale series," an opinion which is shared by his colleagues, MR. BARROW and MR. GIBSON.

Leek District and Cheadle Coal-field. (Mr. George Barrow.)

Resuming work near Leek in the spring, MR. BARROW completed the mapping of the inlier of Bunter strata through which the Churnet flows. In addition, so much of the Carboniferous shales and grits was examined as sufficed to finish the area allotted to him. The examination of the Cheadle coal-field was then commenced, and the same plan was followed as in the previous season. The grit-bands immediately below the Coal-measures were first traced, as it has been found that they indicate clearly the presence and direction of faults, which are so much more difficult to trace in the softer coal-bearing strata. Starting from this basal group, the examination of the overlying groups was proceeded with, and a higher and inner zone was completed, including the Woodhead coal. The tracing of the coal-seams above this horizon has proved difficult and tedious owing to the soft nature of the strata, and the almost featureless character of the country. Indeed some portions of the work could not be done without the assistance of mining information as to the ascertained structure of the ground, and this information has been willingly afforded by those connected with the collieries. The base-line of the Bunter formation which forms the southern limit of the visible coal-field has also been traced, and only a few patches of obscure ground now remain to complete the survey of this area.

Beginning with the oldest or Carboniferous series of strata, MR. BARROW reports that these fall naturally into five groups, which have probably only a comparatively local value. They are as follows in descending order :—

1. The White-weathering group with numerous coal seams. Thickness, 1,200 feet.

2. The Woodhead coal with accompanying dark shales and the Kingsley sandstone below. Thickness, 230 feet.

3. The Dark Shale and Gannister group. Thickness, 300 feet.

4. The first and third Grits with the intervening dark shales ; thickness, 300 feet. (Millstone grit in part.)

5. Dark shales with marls and thin sandstones, the latter passing to coarse grits in a south-easterly direction ; thickness not yet known. Yoredale beds on the maps.)

* See Green, "Geology of Stockport." *Mem. Geol. Survey*, 1866, p. 36.

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1. *The White-weathering Group.*—As no complete account of this group has yet been published, the following section of this part of the Coal-measures in descending order may be given here:— Leek District and Cheadle Coal-field. (Mr. George Barrow.)

	Ft.	In.
Two yard Coal	5	6
Measures	54	0
Getley Coal	2	0
Measures	20	0
Half yard Coal	2	6
Measures	61	0
Yard Coal	3	9
Measures	60	0
Litley Coal	2	9
Measures	35	0
Four-foot Coal	4	0
Measures	60	0
Coal	1	6
Measures	80	0
Dilhorne Coal	6	0
Measures	190	0
Alecs or Stinking Coal	3	9
Measures	55	0
Foxfield Coal	1	8
Measures	64	0
Coal	1	5
Measures	130	0
Cobble Coal	1	3
Measures	55	0
Coal	1	1
Measures	95	0
Rider Coal	1	6
Measures to Woodhead Coal	125	0

Though numerous seams of coal occur in this group, the Yard and the Dilhorne are the only thick seams of good quality. Of the thinner seams the Half-yard and the Cobble are always of fairly good quality, while the others either vary locally or are persistently of a poor character. The strata of this group are characterised in the field by their white weathering, their principal constituent being a pale marly shale or clay. When under pressure this is a fairly hard rock, but when once wetted it rapidly swells up and tends to close up the workings, thus adding greatly to the cost of winning the coal. All coals above the Dilhorne suffer more or less from this disadvantage.

Fresh or brackish-water lamellibranchs occur in thin grey bands throughout the group, while fish-remains, *Spirorbis* and *Carbonia*, are locally abundant. The strata, as a whole, may be claimed as essentially of fresh-water origin.

2. *The Woodhead Coal and Kingsley Rock or Sandstone.*—While the dark shales associated with the Woodhead Coal resemble the beds of the uppermost group in the fresh-water nature of their organic remains, they differ from them greatly in lithological character. In place of being soft, these shales are distinctly hard. In particular, the black shale immediately above the coal has a massive aspect when seen in stream-sections, and forms an excellent roof to the workings. As the floor is also a hard rock,

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Leek District and Cheadle Coal-field. (Mr. George Barrow.)

this coal can be worked cheaply, and it is consequently the only seam at present worked to any extent in the Cheadle coal-field. About eight feet below the coal comes another black shale some thirty feet thick, which rests on the Kingsley rock, an alternation of thin sandstones and laminated hard sandy shales. This rock forms on the surface of the ground an excellent topographical feature, recognisable at a considerable distance. As it passes into the dark shales of the third group below, its limits can hardly be precisely fixed. But its distinctive characters are of great local value, for, as it can be easily recognised, it has supplied the key to the geological structure of the district.

3. *The Black-shale and Gannister Group* is characterised by its great amount of black shale which contains an essentially marine fauna, and thus differs from the higher shales, which otherwise closely resemble it. With the shales of this third group are associated numerous thin coal-seams. Of these all but one are either not persistent, or become so thin as to have often escaped notice. One, however, which is very persistent, is known as the Crabtree or Stinking (pyritous) Coal. It invariably possesses a hard shale roof containing abundant *Goniatites* and other marine fossils. There is reason to believe this coal, with its shale roof, to be continuous into Lancashire, and to regard this portion of the Coal-measures as the equivalent of the Gannister series of the country to the north. This view is strengthened by the fact that the sandstones of this zone often have a gannister-like aspect. Indeed the sandy beds below the Crabtree Coal often pass into a high-class gannister, which is now being worked in two places. At the base of this group lies the well-known Froghall Ironstone, which has been extensively worked in the Consall, Froghall, and Ipstones district. Detailed examination shows this seam to have been lenticular in form; practically the whole of the lenticle has been worked out. A feature worth noting in it is the fact that near Ipstones lenticles of coal occur in its upper part. The same phenomenon has been noted in connection with two ferruginous bands in the horizon below.

4. *Millstone Grit* (in part).—This group consists of the First and Third Grits, with the mass of dark shale between. In the area about Froghall and Ipstones these bands show much the same character and thickness as about Leek; the grits are probably slightly thinner, but the difference is not great. The shales between the grits are interesting, as they contain two hard shale-bands closely resembling the shale above the Crabtree Coal. The first lies about half way between the two grits, and is underlain by a mixture of coal and ironstone, the exact thickness of which has not been ascertained. The second shale-band lies about 10 feet above the Third Grit, and is underlain by the well-known Roaches Coal, which appears to extend like the Crabtree seam over a very large area. Unlike the latter seam, however, it thickens and thins locally, and in some places becomes little more than a smut. To the west of Ipstones this Roaches Coal is 2 feet 10 inches thick, and of fairly good quality.

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A level which was driven into it to drain the water may be at least 300 years old. At the time when this level was made its construction must have been a feat of engineering. The fact that mining operations long ago attained a high standard of excellence in this part of Staffordshire is borne out by the discovery of extensive workings in the Froghall ironstone in the course of the more recent mining operations. All record of these workings is lost, yet it is clear that at least several thousand tons of ironstone must have been extracted from them. As the coal above the Third Grit is traced southward an association of interlaminated coal and ironstone is met with, similar to that in the two instances just mentioned. It is remarkable that the same somewhat exceptional conditions should have been repeated three times in the same area on different horizons. Such an association of coal and ironstone has not been met with on these horizons in any other part of the region. Leek District and Cheadle Coal-field. (Mr. George Barrow.)

On the west side of the Cheadle coal-field a very different development of these strata is met with. Starting from the cross-roads south of Wetley and proceeding towards Dilhorne, we find that the first grit thins away with great rapidity and indeed is no longer recognisable. The third becomes much thinner, though still sufficiently coarse to be distinguishable from an ordinary Coal-measure sandstone. If this rate of thinning were continued, in a short distance there would be little or no grit left. The cover of Bunter sandstone which comes on further south makes it impossible to say whether or not such a diminution takes place.

5. *The Zone below the Third Grit.*—A small portion of the rocks below the Third Grit has been mapped on both the east and west sides of the Cheadle coal-field. To the east, across the Churnet Valley, where the grits above are still thick, we find below the Third Grit, first a mass of dark shales associated with bands of marl and thin sandstone. Below these lie a number of comparatively thin bands of coarse grit. As this area is much faulted, these grits gave considerable trouble in the mapping, for they seemed to be parts of the Third Grit repeated by faulting. Fortunately the thickest of them has been sunk through and found to be only 30 feet thick, so that it could not be that bed. The detailed survey of the area has proved these grits to occupy the horizons of the thin hard sandstones (crowstones) of the Leek and Endon district, and it is now seen that the great mass of shale and sandstone of that district is a somewhat local phenomenon, for to the south-east these rocks revert to their more normal condition of coarse grits. On the east side of the Cheadle coal-field, however, where the grits are thinning away, no such coarse rocks occur in this lower zone. Though hardly so fine as the typical "crowstones" the sandy rocks are still fine in grain.

The progress of Mr. Barrow's field-work has once more impressed upon him the great vertical range of individual fossils in the Carboniferous system, and he contrasts the *Goniatites*

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of that system with the *Ammonites* of the Yorkshire Lias. If the rate of biological variation remained fairly uniform we must suppose that the Carboniferous strata were laid down with comparative rapidity. In the case of the grits and shales this acceleration of sedimentation may not present any serious difficulty, but it is not so credible in the case of the great mass of Carboniferous Limestone.

North Staffordshire Coal-field. (Mr. W. Gibson.)

The continued prosecution of the resurvey of the Pottery coal-field has been carried on by MR. GIBSON, partly with the assistance of MR. WEDD, while the surrounding Triassic areas have been mapped by MESSRS. POCOCK and WEDD. The following narrative of the work has been drawn up by MR. GIBSON:—

Among the Carboniferous rocks, several observations of scientific interest and commercial value have been made. At Weston Sprink, on a horizon between the Moss and Yard Coal, some purple shales, marls, and thin limestones are exposed in a marl pit. The shales have been traced some distance northward and found to be overlain by a red sandstone similar in appearance and texture to the Keele sandstone at the top of the Coal-measures. MR. JOHN WARD, of Longton, has obtained an interesting set of marine forms from this place. The fossils include *Aviculopecten papyraceus, Discina nitida, Lingula mytiloides, Pleuronautilus* sp., also a mytiliform shell and a small estheroid shell. The occurrence of *Aviculopecten papyraceus*, etc., high up in the Coal-measures is new to science.

Mention was made in the last *Summary of Progress* (p. 127), of the discovery by MR. GIBSON of an ironstone in Fenton Park marl pit, of which DR. POLLARD made an analysis from a carefully selected set of examples. A similar ore was found during the past year underlying the Chalky Mine Ironstone at the Clanway Colliery, Tunstall.

By the courtesy of MR. W. B. CLIVE, an analysis of this ore by MR. W. JACKSON, A.R.C.S., is here given:—

Ferrous oxide -	38·88 per cent.	= 30·24 per cent.	iron.
Manganous oxide -	0·89 „	= 0·69 „	manganese.
Lime - - -	6·09		
Magnesia - -	3·34		
Alumina - -	7·90		
Silica - - -	12·10		
Phosphoric acid -	0·53		
Carbon dioxide -	27·52		
Water (lost at 100°)	0·85		
Combined water -	2·78		
	100·88		

On calcined stone 41·33 per cent. iron.

The ore lies directly under and contiguous to the Chalky Ironstone bands. This position makes it a valuable ore, since although of comparatively low grade, it can be got with the valuable Chalky Ironstone at little extra cost. It is hoped, therefore, that the ore will ultimately be used in the local blast-furnaces.

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In the difficult region of Talke and Audley, MR. WEDD has found that the lowest productive Coal-measures are brought to or near the surface in anticlines which trend in a north-north-east direction, from Woodlane on the south to Harecastle on the north. The Ten Feet Rock, a thick sandstone above the Ten Feet Coal, and sometimes in conjunction with the "rock" associated with the Seven Feet Banbury Coal, plays a large part in the formation of the anticlinal ridges. As the highly-inclined seams are traced on the western limb of the anticline they are found at a comparatively shallow depth to bend sharply upward, and to assume an almost horizontal position up to a large fault, which can be followed from Madeley Manor to Audley Station, and has been variously estimated to have a downthrow of more than 300 yards to the west. On the downthrow side of this dislocation the strata are gently inclined to the west. This inclination has been proved by mining operations to hold for the lower coals, and can also be seen at the surface in the upper measures. North Staffordshire Coal-field. (Mr. C. B. Wedd.)

West of Leycett and Audley Station the Etruria marls and Newcastle-under-Lyme series, as described in last *Summary of Progress*, dip to the west at a gentle angle. The field-work during the past year thus enables us to define more clearly the area occupied by Upper Coal-measures to the west of the Staffordshire anticline. The area exposed may be taken at two square miles. Under this tract the Bassey Mine Ironstone lies at a depth of 1,000—1,300 feet.

A band of limestone containing *Entomostraca* has been found in the Keele series at Moddershall. This band most likely lies at a higher horizon than those described in the *Summary* for 1898. A cream-white limestone has also been found in the Keele series in the Keele Park railway cutting, 311 feet above a dark limestone containing Entomostracan remains; obscure forms of plants have also been found in the same cutting. During the progress of some excavations in Keele Park, a coal one foot six inches thick was found in the red series. Some good, but unnamed, specimens of plants from the Keele Sandstone of Hartshill, from the collection of the late DR. GARNER, are preserved in the Museum of Stoke-upon-Trent. These, at MR. GIBSON'S request, have been examined by MR. KIDSTON, F.R.S.E., who has kindly furnished the following list of them :—

Sigillaria tessellata, Brongn, decorticated and showing fructification zone.
Calamites undulata, Sternb, &c.
„ *Schutzei*, Stur.
„ *Cistii*, Brongn.?
„ *Suckowii*, Brongn.

These additional facts tend to show that the Keele Sandstone series, as already suggested, is intimately connected with the Coal-measures.

A thin band of grey limestone with *Entomostraca* has also been found near the base of the Etruria marls in the Grange Marl Pit. Eleven distinct bands containing *Entomostraca* are

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North Staffordshire Coal-field. (Mr. W. Gibson.)

now proved to exist in the Upper Coal-measures of North Staffordshire. They are distributed as follows through the several sub-divisions of that assemblage of strata:—

KEELE SERIES:—Four bands at different horizons:—*Carbonia, Spirorbis.*

NEWCASTLE-UNDER-LYME SERIES:—Two bands near the base:—*Carbonia, Spirorbis, Anthracomya calcifera.** Fish-remains.

ETRURIA MARL SERIES:—Two bands near the summit and base:—*Spirorbis, Carbonia.*

BLACK BAND SERIES:—Three bands near the base, and thin bands of black shale with *Entomostraca* at several horizons:—*Carbonia, Spirorbis, Anthracomya Phillipsi, Carbonicola Vinti.** Fish-remains.

While examining the cores from the bore-hole at Thurgarton, near Nottingham, MR. GIBSON has made an important observation. He has found that the marls with *Productus horridus* rest on some red sandstones, identical in lithological character with the Keele Sandstone. The base of the Permian marls is a breccia, suggestive of a break between the Zechstein and Red Sandstone and Marls. Plant-remains are common at one horizon among the red sandstone and marls in the bore, and some of them have been sent to MR. KIDSTON for identification. The red sandstones have a dark calcareous shale with *Entomostraca* at their base, and are underlain by grey measures resembling the sandstones and shales of the Newcastle-under-Lyme Series. This is confirmed by the occurrence below these grey measures of mottled red marls, containing thin bands of coarse green grits like those so characteristic of the Etruria Marl Series in North Staffordshire. These red marls at Thurgarton pass down into grey measures containing Coal-seams. The recognition therefore of the divisions into which the Upper Coal-measures of North Staffordshire can be divided has thus great economical importance, as it enables us to detect the coal-bearing strata, and to fix their stratigraphical position under the Permian and younger formations of the centre of England.

Cheshire.

Macclesfield District. (Mr. Pocock.)

In order to complete the one-inch map which contains the northern part of the North Staffordshire Coal-field (No. 110) it has been necessary to revise the ground that stretches northward into Cheshire. Accordingly MR. POCOCK was stationed at Macclesfield with instructions to revise the Carboniferous tract to the east of that town. The district, which during the past year has been examined by him, lies between Macclesfield and the articlinal fault described by the late PROF. GREEN as running in a north and south direction, four miles further east.

The general structure of the ground has been well described by PROF. HULL and PROF. GREEN in their Memoir "On the Geology of Stockport, Macclesfield, Congleton, and Leek," but

* Dr. Wheelton Hind. *Quart. Journ. Geol. Soc.*, vol. lv. (1889), p. 367.

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some modifications of detail have been found necessary, in order to bring the mapping into harmony with the revised ground further south. The outlier of the fifth Grit, represented on the published map to the north-west of Forest Chapel, and the band of the same rock between Walker Barn and Tup Close Farm proved, after careful examination, to form really one continuous outcrop with the Yoredale Grit immediately to the east. This outcrop is repeated by a set of cross faults, one with a northerly trend, and the other pointing a little north of east. Half a mile west of Forest Chapel the strata arch over to the west, and the same grit appears with a westerly dip, succeeded by another, which crops out on the edge of Langley reservoir. The latter band is referred to in the Memoir as the Yoredale Grit, but is not shown on the published map. A mile further west, the escarpment of Tugg's Nose, which rises abruptly 550 feet above the valley, clearly represents three grits, and not merely the third and fourth, as shown on the map. The succession between this place and Forest Chapel, as well as on the west side, is complicated by faults. The belts of shale separating the different members of the grit series appear to be faulted out on the high ground east of Macclesfield, though they can be seen in the deep brook-sections to the north. Macclesfield District. (Mr. Pocock.)

South Wales.

During the past year the field-work in South Wales has lain chiefly in the region between Swansea and the northern edge of the coal-field (Sheets 230 and 247), but has included also the eastern part of the Gower peninsula, and a small tract near Bridgend (Sheet 262). Mr. Tiddeman, having completed the area assigned to him at Bridgend, commenced the examination of the Limestone and Coal-measures of Gower. Mr. Strahan surveyed the ground east of the Tawe from Swansea to Ystalyfera, and part of the north crop, while Mr. Cantrill carried on the examination of the north crop, and of the Millstone Grit and Limestone beyond it. Mr. Gibson was engaged for a short time in completing an area near Neath, upon which he had been engaged before his transference to Staffordshire. S. Wales. (Mr. Strahan.)

The following account of the past season's work of the staff in South Wales has been drawn up by Mr. Strahan, to whom his colleagues have supplied notes regarding the ground surveyed by them.

Carboniferous Limestone.—The limestones of Gower are described by Mr. Tiddeman, so far as his investigations have gone, as being similar to those of the anticline between Cowbridge, Bridgend, and Porthcawl. They consist chiefly of grey rock, more often dark than light, with also shades of buff. Some of the oolitic bands weather white. Crinoidal limestones are not common among them. The greater part of the rock consists of fine current-bedded organic *débris*. Another common type shows an almost black stone, containing small organisms and

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S. Wales. (Mr. Tiddeman.)

larger nests of white crystals, which may represent the remains of shells or corals. The oolitic limestones range in tint from almost black to nearly cream colour.

A curious set of limestones occurs along the north side of Mumbles Head. There are at least three which assume the appearance of a breccia. But the fact that the interstices between the apparent fragments are sometimes occupied by dolomite suggests that the rock is not a true breccia, but has been dolomitised along cracks. The surfaces of some other bands are marked with a number of small pits, most of which contain an irregular nodule, also apparently of dolomite. The edges of these pits frequently rise above the surrounding surface, as though there had been some obstacle to regular deposition. Similar strata were noticed by MR. TIDDEMAN at Newton Nottage, fourteen miles to the east of Mumbles.

A limestone known as "Black Lias," which forms a rampart-like scarp on the seaside of Oystermouth Castle, closely resembles the normal form of Lower Lias, but contains Carboniferous fossils. It is used for building and road-metal, and will make cement. It is black, but becomes coated with a fine white powder on exposure to weather. Occasionally, between strong joints, the stone has decayed to a kind of rotten stone, and MR. TIDDEMAN suggests that it may be represented by some white clays with *Fenestella* and casts of crinoids, and some thin bands of disintegrated chert, which crop out further west. The clay was formerly worked at the Croft on Langland Road, on the opposite side of the glen, and south of Newton.

The general structure of the area of Carboniferous Limestone in Gower may be described as that of a great compound anticline, striking generally W. 16° N., and broadening to the west, where eventually the Old Red Sandstone comes to the surface. The anticline is crossed by many small faults, ranging from north-north-west to N. 10° E. in direction, but it is also greatly folded and traversed by faults which run along the strike, and even coincide for long distances with the bedding, only here and there showing their true nature by a slight transgression. Notable instances where the beds are nearly vertical, and where evidently a fault strikes along a compound anticline, occur at Three Cliffs Bay and Sheer Cwm.

One of the largest folds of the compound anticline is that of Oystermouth, which is enclosed between the main mass of the limestone of the Mumbles Head and the road to Newton. The soft strata overlying the limestone are let in here. A fault running nearly along the road brings up to the north the limestone on which Oystermouth Castle stands. On the south side the boundary is probably natural, but the strata are vertical. Much of the Gower limestone has undergone dolomitisation, a change of composition for the investigation of which the services of a chemist were needed. DR. POLLARD was accordingly instructed to make a careful examination of the extent and mode of occurrence of the dolomitisation, and to collect such specimens as might be necessary for analysis. So far as the observations

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have gone at present, MR. TIDDEMAN infers that all the limestones are liable to the change; that the alteration takes place along both planes of bedding and faults; that it occurs at all elevations, but apparently reaches its greatest development low down by the sea. S. Wales. (Mr. Cantrill.)

The Carboniferous Limestone of the neighbourhood of Cowbridge, the surveying of which has now been completed by MR. CANTRILL, forms part of the Cowbridge-Cardiff anticline. The shales which underlie the main mass of the limestone appear to crop out in the bottom of the valley of the Dawen, while the overlying rock forms the precipitous western side. The greater part of the main limestone is concealed under Secondary rocks, but it seems to consist in the lower part of dark crinoidal limestone, succeeded upwards by light-coloured oolite.

In the north crop MR. CANTRILL has continued for some miles the tracing of the highest subdivision of the series, namely some shales with their black limestones. The rotten-stone, into which the limestones weather at the outcrop, becomes less pure westwards, and the whole band grows less important, but the workings have been continued, wherever the outcrop is sufficiently free from drift or grit *débris*.

Millstone Grit.—The pebbly conglomerate which forms the lower part of the Millstone Grit of the north crop continues to be well developed as far westwards as the field-work has been carried. Its rugged grit-scarps are excellently shown on the eastern side of the Twrch Valley at Tyle Garw, and here may be seen, not far from its base, a thin band of black pyritous shale with thin black limestones containing brachiopoda. The rock has at times decomposed into loose *débris*, apparently through the dissolving out of a siliceous cement. This incoherent or friable material has been dug for silica for lining steel furnaces, and the Black Mountain Company is now quarrying a bed of soft grit for the same purpose. Hard unweathered grit is also ground up and used for the same purpose, the multitude of boulders in the bed of the Twrch being thus turned to account.

The middle or shaly portion of the Millstone Grit, exposed in several of the moorland ravines, passes up into a set of thin impersistent sandstones with shales, which form a poor representative of the Farewell Rock. The line of division between the Millstone Grit and Coal-measures is purely arbitrary.

The strata lying next above the Carboniferous Limestone of Gower consist of black, thinly-bedded shales with *Posidonomya*, *Goniatites*, *Euomphalus*, &c. These were shown in the original edition of the map as Coal-measures, but they more nearly resemble shales associated with the Millstone Grit. To this formation also may be probably assigned some hard olive-coloured sandstones and shales, with some siliceous rootbeds which crop out near Liliput. The siliceous bands, which are not unlike Cockshot rocks, were proved by DE LA BECHE to be the floors of thin coal-seams.

Coal-measures.—The examination of the Coal-measures has been continued as far west as Cwm Llynfell on the north cr

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S. Wales. (Mr. Strahan.)

and up to the east side of the Tawe between Pontardawe and Swansea. The surveying of the Cwmavon district having been completed, that of the Coal-measures which traverse Gower has been commenced.

In the north crop, where MR. STRAHAN was engaged with MR. CANTRILL in tracing the outcrops of the lower seams, the disturbances which have been already alluded to* acquire special importance from the fact that they here affect the lower portion of the Coal-measures. Not only are the seams over-folded and over-thrust, but the whole mass of sedimentary material has undergone deformation. The few shaft-sections which are obtainable do not therefore give the normal distances between the seams, and we have to rely upon estimates obtained by averaging data collected over a considerable area. The following table is based upon the consideration of a number of workings extending from Ystradgynlais to Gwaun-cae-gurwen:—

COMPARATIVE SECTIONS ALONG THE NORTH CROP, FROM GARNANT TO THE VALE OF NEATH.

—	Garnant and Brynamman.	Ystradgynlais and neighbourhood.	Dulais and Neath Valleys.
	Yards.	Yards.	Yards.
Stwrain Coal Measures	10	—	15 Upper or White Four-Feet Vein.
White Vein Measures	5 to 9	8	
Black Vein Measures	22†	21†	19 Eighteen-Feet Vein
Little or Four-Feet Vein Measures	10 to 18	24†	15 Cornish Vein.
Harnlo Vein Measures	19 to 22	25	13 Harnlo Vein. 11 Nine-Feet Vein.
Big Vein Measures with a Black Vein	34 to 45	28 to 20	20 Yard Vein.
Brass Vein Measures	18	19	21 Two-Feet Vein.
Trigloin Vein Measures with Brynlloi, Little Brass, Middle, and Lower Veins	45 (supposed)	34 (supposed)	Measures with the Bluers, Enoch, Rhyd, and Grey (?Cnapiog) Veins, 78 (supposed).

All of these seams are anthracitic. The Four Feet or Little Vein, the Big, and the Brass, have been the most extensively worked. The first-named was raised principally in connection

* *Summary of Progress* for 1898, pp. 116-119.
† This figure is arrived at by averaging several sections.

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with some noted ironstone, and is now scarcely being touched. The veins below the Brass Vein are worked in Cwm Twrch, but not further to the east. S. Wales. (Mr. Strahan.)

The disturbances take the form of acute folds which range in direction from about north-east at Cwm Llynfell to nearly east at Palleg. They thus cross the north-and-south system of normal faults almost at right angles. It seldom happens, however, that one of these "slip-faults" can be traced far in the disturbed ground. Sharp as many of the folds are, the coal has proved hard and workable both over the anticlines and down into the synclines, except on small strips upon the apices of the folds. Not infrequently the compression has reached a stage at which folding no longer sufficed to afford relief, and in such cases fracture ensued, and an overthrust or "overleaf" was produced. Many small and large examples of such structures may be examined in the old patch-works above Gyrnos, but one of the most instructive has been worked out in detail at the Palleg Colliery by Mr. H. Huxham, from whose paper* the materials for the accompanying figure have been taken by his kind permission. The fold shown in the upper section is exposed to view in the precipitous side of the valley; in the second and third sections, which were drawn about 100 and 200 yards respectively further west, this fold has passed into an overthrust, which was fully explored in working the Brass Vein. The quantity of Brass Vein available was considerably increased by the overthrust, and the Big Vein, which had been previously worked, is said to have been thrice overthrust, so as to occur in three "overleaves," in this same ground.

To some such structure as this must be attributed a repetition of the outcrops at Ystradgynlais for which no explanation has hitherto been forthcoming. The Four Foot, Big, and Brass Veins crop out in the hillside between Ystradgynlais Colliery and the Hendre-ladis branch railway, with a steady dip to the south-east. Yet in the Giedd, more than half-a-mile to the north-west, where their position should be high in the air, these veins crop out a second time. The repetition would be accounted for by a fault running about south-west with a downthrow northwards of upwards of 200 yards, and it has been generally assumed that such a fault exists and runs under Ystrad-fawr, near the Hendre-ladis New Pit, by Penrhos and up the Tawe Valley to the Lamb and Flag Inn. This Cwm-ddu Fault, as it is called, must, however, be supposed to cross the outcrops of the Four Foot, Big, and Brass Veins near the Castle Inn, where there is no break in their continuity, while to the south-west it would range for a part of the Tawe Valley, where the crop of the Red Vein seems to disprove the existence of a fault of any magnitude.

It would be impossible to describe in detail all the forms assumed by the strata in the disturbed belt of ground, but it may be mentioned that sharp folding may be seen in the old Cwm Phil patches; at Melin Palleg and in the Twrch Valley close by, as well as at the Palleg Colliery; in the Gwys Valley near Tir-y-gof;

* *Proc. South Wales Inst. Eng.*, vol. xx., p. 189, and vol. xxi., p. 2, 1898.

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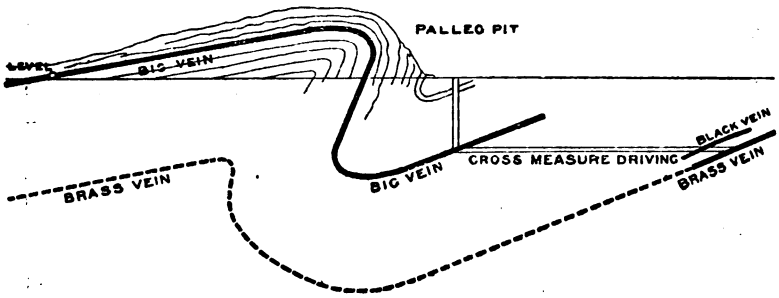
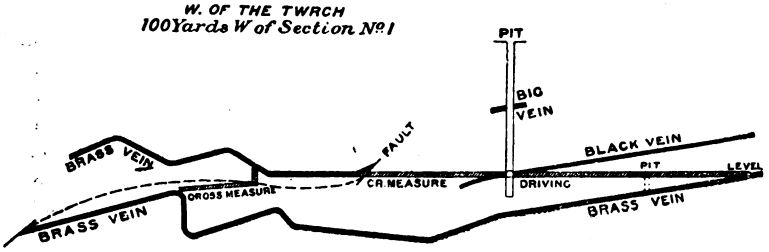
SECTIONS SHEWING THE PASSAGE OF THE PALLEG MONOCLINE INTO THE BRYN MORGAN OVERTHRUST.

Re-drawn by permission from a paper by Mr H.Huxham
Proc. S.Wales Inst. Eng. Vol.XX.

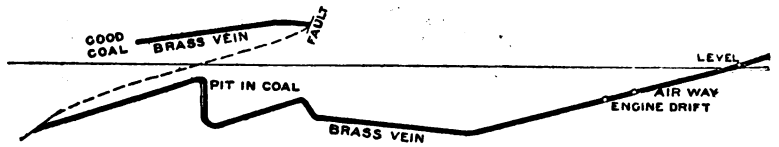
SECTION No 1
E. OF THE TWRCH

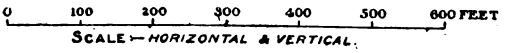


SECTION No 2.
W. OF THE TWRCH
100 Yards W of Section No 1



SECTION No 3.
about 100 Yards W. of Section No 2





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in the Twrch Valley from Bryn Henllys to near the silica-works; and in Cwm Llynfell. Similar rolls occur in the old patch-works at Brynamman and in the Garw Valley, while some parallel disturbances have been noted by MR. CANTRILL in the Millstone Grit of Gareg-lwyd and Tair Carn. S. Wales. (Mr. Cantrill.)

The largest of the north-and-south faults which cross this part of the north crop is known as the Cwm Llynfell or Bryn-llefrith Fault. It is a downthrow to the west of about 240 yards, and falls into line with the Rhydding Fault so far as that has yet been traced. Another important fault crosses the Twrch river near the silica-works, and has been proved in the workings of the Brass Vein across the mountain to near the Gwys river. This also is a downthrow to the west, and forms the eastern limit of the field of the Brass Vein. Two important faults have been shown by MR. CANTRILL to throw down the trough of Millstone Grit which forms Esgair Hir.

The folding of the strata here described is almost wholly confined to the outcrop of the lower measures, and the Red Vein crops with great regularity round hill after hill. It would not be prudent, however, to assume that the lower strata are not similarly folded under those hills, for experience gained in other parts of the Coal-field has taught that soft measures of this type though highly contorted themselves may be directly overlain by strata in which no disturbance is manifest.*

The Red Vein, which is about 3½ feet thick, lies about 170 yards above the Stwrain Vein, the highest of the seams mentioned in the table given above. It is worked at the Farteg Colliery, Ynysygeinon and Ystalyfera. At the Ynysygeinon Colliery it is thrown down westwards by two faults of forty and sixty yards respectively, one on each side of the level. The former dies away southwards, but the sixty-yard fault runs just east of Daren Wyddon and traverses the mountain for some distance. A branch of it with a westerly downthrow of about twenty yards is well seen in the southern angle of Daren Wyddon. The veins above the Red Vein consist in ascending order of the Welsh, the Pinchin and the Ynysarwed, none of which are at present worked in the area surveyed last year. The last-named represents No. 2 Rhondda, and lies at the foot of a conspicuous rock-feature; as at Crynant, there is a conglomerate band with pebbles of quartz and ironstone, a yard or two above the coal. The seam is visible in Daren Wyddon and Taren-y-gigfran, and it has been worked at the outcrop as far as Cwm Clic. In that ravine it has been recently driven into for about 200 yards, but being in troubled ground and the coal being a bastard-anthracite for which there was no good market, the workings were not profitable. The distance from the Ynysarwed Vein to the Red Vein can be calculated at the old pit at Ynysygeinon Junction. The Ynysarwed crops out 310 feet above the pit, and the Red Vein was reached in the pit at about 130 or 140 yards. Making

* *Summary of Progress* for 1898, p. 116.

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S. Wales. (Mr. Strahan, Mr. Gibson.)

allowance for the dip we get about 260 or 270 yards as the distance between the veins, as compared with 270 yards in the Dulais Valley.

Above the Ynysarwed, or No. 2 Rhondda, lies a great mass of almost unproductive measures, chiefly composed of Pennant Grit, with subordinate beds of shale, and a few bands of quartz-rock. This barren zone has hitherto proved a complete barrier between the productive upper measures of Swansea and those which have been described above. These productive upper measures may be considered to commence with the vein which is variously known as the Esgirn at Cwmavon, the Hughes Vein at Swansea, and the Wenallt at Neath and east of it, and the determination of the distance from the Ynysarwed to the Hughes Vein thus becomes of the greatest importance in view of the probability of deep explorations being carried out in the central parts of the Coal-field. An estimate therefore has been made from more than one source.

In the Neath Valley, the Clyne Shaft started 500 feet below the crop of the Wenallt Seam, and at a depth of 209 yards reached a coal, 2 ft. 10 in. thick, which was supposed to be No. 1 Rhondda. The crop of the Wenallt seam is 2,000 feet distant from the pit, and allowing a dip of 5° we get 434 yards as the true distance from the Ynysarwed to this supposed No 1 Rhondda. This distance, however, is too great, and the seam was probably No. 2 Rhondda, for in Cwm Cregen in the Cymmer Valley, MR. GIBSON finds the Wenallt to be 332 yards above No. 1 Rhondda, and 432 yards above No. 2 Rhondda. Again in the Cadoxton Pit, which starts twenty yards below the Gellia (Wenallt) Seam, and extends to a depth (including a borehole of 403½ feet) of 397 yards below that seam, no representative of No. 2 Rhondda has been found. Lastly a section has been plotted through Mynydd March Hywell, under which the Wenallt seam has been almost continuously worked under the name of the Gellia Vein* to the crop of the Ynysarwed Vein at Cwm Clic, with the result of showing that there must be not less than 420 yards of strata between the two veins. We may assume then that the actual distance from the Wenallt to the No. 2 Rhondda seam in the Tawe and Neath valleys lies between 420 and 440 yards.

The Wenallt or Hughes Vein is one of a group which has been extensively worked near Swansea. The group includes, in descending order, the Dirty, the Rhesog, the Slaty, the Curly, the Bodwr or Rotten, and the Hughes. Of these, one only exists in workable form at Neath and in the Tawe valley above Llansamlet, and whether that one represents the Hughes or the Bodwr is open to doubt.

The distance from the Graigola to the Hughes Seam has

* This seam is locally called the Graigola. During the past year, however, MR. STRAHAN has found that the true Graigola Vein lies about 230 yards higher up. A passage in last year's *Summary of Progress*, p. 115, in which the Graigola is correlated with the Wenallt requires modification. It is the so-called Graigola of Mynydd March Hywell which may be so correlated.

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recently been proved by a shaft at Waun-y-coed near Pontardawe. The sinking commenced 20 yards below the crop of the Graigola and proved the Hughes at 216 yards. Allowing for a small dip we may take 234 yards as the distance between the two seams. S. Wales. (Mr. Strahan.)

From the Graigola upwards the section has been proved at the Dyffryn Main and Primrose Collieries. We may, therefore, proceed to construct a table showing the thicknesses of the measures of the Neath Trough, from the highest existent down to the lowest which may be inferred to exist from what can be seen at the North Crop.

	Thickness.		Depth below Bryn Coch Vein.	
	yds.	ft.	yds.	ft.
Bryn Coch Vein				
Measures	152	2	152	2
Wernffraith or Primrose Seam				
Measures about 105 yards				
Greenway or Court Herbert Seam, impersistent at Dyffryn	226	0	378	2
Measures about 130 yards				
Little Tyr Edmond Seam				
Measures	2	0	380	2
Lower Tyr Edmond or Victoria Seam (the Hard and the Brithdir Vein)				
Measures	25	2	406	1
Graigola or Greenway Vein of Gnoll				
Measures, 37 yards				
Upper Maesmelyn Vein				
Measures, 50 yards	234	0	604	1
Lower Maesmelyn at Waun-y-coed				
Measures				
Wenallt or Hughes Vein				
Measures	420	0	1,060	1
No. 2 Rhondda or Ynysarwed Vein				
Measures 260 to	270	0	1,330	1
Red Vein				
Measures about	200	0	1,530	1
Four Feet, Little, or Pencraig Vein				
Measures 33 to	40	0	1,570	1
Big Vein				
Measures from 20 to 45 yards say	35	0	1,605	1
Brass Vein				
Measures with Trigloin, Bryn-lloi, Middle, and Lower Veins about	100	0	1,755	1

It must be borne in mind that in this Table the measurements given for the strata below No. 2 Rhondda were obtained in the North Crop and that, in accordance with the general rule that the Coal-measures thicken southwards and westwards in South Wales, they would be considerably thicker under Neath. Further light may be thrown on the point when the South Crop has been more fully examined.

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S. Wales. (Mr. Strahan)

The Neath section differs materially from that of East Glamorganshire. The No. 1 Llantwit, which may be taken to be the equivalent of the Mynyddislwyn of Monmouthshire, probably corresponds to the Wernffraith. Hughes Vein corresponds to the Wenallt, which, as was pointed out in the *Summary of Progress* for 1898 (p. 115), is probably the Pen-y-groes Vein of Llantwit Fardre. The Stwrain of Cwm Twrch is believed to be the Two Foot Nine Seam, while the Big Vein corresponds to the Nine Foot or Ras-las.

At Llantwit the No. 1 Llantwit lies 115 yards above the No. 3 Llantwit;* No. 3 Llantwit 60 yards above the Pen-y-groes Vein. At the Glyn Colliery the Tydu Vein, which is probably the Pen-y-groes Vein, may be estimated to lie about 270 yards above the No. 2 Rhondda, the distance between the two outcrops being 360 yards and the dip varying from 40° to 52°. The distance from the No. 2 Rhondda to the Two Foot Nine Seam has been proved in the Rhondda Valleys to average 300 yards, while in the same district the distance from the Two Foot Nine to the Big Vein ranges from 60 yards near Aberdare to 113 yards at Clydach Vale. We are thus able to construct the following comparative sections to illustrate the thickening of the measures in a horizontal distance of 20 to 25 miles. The most rapid expansion shows a rate of 1 in 116, which is by no means improbably great.

Neath Trough.	Yards.	Rhondda Valleys and Llantwit Fardre.	Yards.
Wernffraith Seam		Llantwit No. 1	
Measures 454 yards Graigola Seam Measures 234 yards in the Tawe Valley	488	Measures - - -	175
Hughes Vein		Tydu Vein	
Measures - - -	420	Measures - - -	270
Ynysarwed Vein		No. 2 Rhondda	
Measures - - -	440	Measures - - -	300
Stwrain Vein		Two Feet-Nine Seam	
Measures - - -	70 to 80	Measures - - -	60 to 113
Big Vein		Nine Feet Seam	
Measures - - -	20 to 35	Measures - - -	—
Brass Vein			

In the neighbourhood of Swansea only the Hughes and the veins above it are worked. The various seams are identifiable without much difficulty as far west as the Gardener's Fault, a downthrow of more than 300 yards to the west, which runs up Cwm Crymlyn by the Birchgrove Pit to Glais. The seams which are thrown in at Llansamlet on the west side of this fault are commonly stated to be bituminous, while those on the east are steam-coals, a statement which is true to the extent that, owing to the large displacement of the fault, seams belonging to the more highly bituminous upper part of the Coal-measures are thrown face to face with those belonging to a lower and more

* See Vertical Section of the Geological Survey Sheet, No. 81, section No. 6.

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anthracitic zone. The correlation of the seams has been attended with some difficulty, partly owing to the fact that every shaft on the west of the fault has been sunk on a fault, and that for many years the true sequence of measures remained unknown, and partly in consequence of considerable changes undergone by the seams in that neighbourhood. The following table gives the most probable identification:— S. Wales. (Mr. Strahan, Mr. Tiddeman.)

Llansamlet (West of the Gardener's Fault).	Yds.	Neath Trough (East of the Gardener's Fault).	Yds.
Drew's Vein Measures	165	Bryn Coch Vein	152
Four Feet Seam Measures	118	Wernffraith Vein	254
Five Feet Seam Measures	118		
Six Feet Seam Measures	20	Graigola Seam	
Three Feet Seam Measures	44		
Two Feet Seam Measures, including four or five workable seams in their lower part	271	Not proved, but about	240
Hughes Seam		Hughes Seam	

It would appear, therefore, that the Brithdir or Tyr Edmond Seam is absent on the west side of the fault, while, on the other hand, the group of seams which at Swansea occurs close above the Hughes Vein, is represented by one, or perhaps by two seams at Neath.

The surveying of the Bryn and Cwmafon district has now been completed by Mr. Tiddeman. He finds that the strong rock-feature which he traced through much of the Maesteg district under the name of the Llynfi Rock is the same as that called the Tormynydd Rock further west. The Wernpystill Seam, which lies above that rock, and not the Tormynydd which lies below it, will therefore represent the No. 2 Rhondda Seam, which has been selected as the base of the Pennant series. The Cockshot Rock, another distinctive horizon, has been traced to the foreshore near Baglan School.

The series of coal-seams below the representative of No. 2 Rhondda is as follows:—

The Tormynydd, which proves well from Cwmafon to Bryn.
The Jonah is thin throughout.
The White Seam is about 4 feet thick, and is regular from Cwmafon to Maesteg.
The Clay Seam proves well with a thickness of about 2 ft. 4 in.
The Cwm Mawr Seam is thick near Cwmafon, but thin from Bryn to Dyrysiog. It is considered to correspond to the Victoria Seam of Maesteg.
The Golden Vein has been worked by level from Cwmafon to Bryn collieries, and is about 3 feet thick. It is believed to correspond to the Two and a half Feet seam of Maesteg.
The Cockshot Seam rests upon or close above the Cockshot Rock and consists of two coals, 2 ft. and 2½ ft. thick. It represents the Caedefaid o the Llynfi, Ogmore, and Garw valleys

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S. Wales. (Mr. Strahan.)

The Finery Seam was formerly worked at Bryn on the anticline adjoining the Moel Gilau Fault, at Bryn Gyrnos and also at Cwmafon. It was much esteemed for copper-smelting.

This is followed in descending order by the Upper Four Feet, the Big Seam, the Coal and Mine Seam, the Lower Four Feet, the Four and Five Feet Seam and the Yard Seam, some of which have been worked about Cwmafon.

The Park Colliery Shaft at Baglan struck the Big Vein at 90 yards depth, but the ground was much disturbed owing to the nearness of the Moel Gilau Fault.

FAULTS.—*The Gnoll Fault.*—This great fault runs from the South Crop near Cwmafon to the Neath Valley near Llantwit by Neath. At Cwmafon it was proved in the working of the lower coals to be a downthrow to the west of about 70 yards, but at the Gnoll its throw must be between 400 and 500 yards, for at this point it brings the Court Herbert Seam nearly on a level with the Glyngwilym. Now the Court Herbert Seam is the Greenway Seam of Dyffryn, which lies 150 yards above the Graigola, and therefore about 390 yards above the Hughes or Wenallt. The Glyngwilym lies about 50 yards below the Wenallt, giving the total distance between the Court Herbert and Glyngwilym Seam as 440 yards.

The direction of the Gnoll Fault from Cwmafon to Gnoll is almost due north, but at the latter place it was proved in the workings of the Graigola Seam, and may be seen on the surface also, to turn to the north-west, the furthest point to which it has been proved being nearly under the Neath Workhouse. Its course from this point has been the subject of much dispute. It certainly does not cross the Gellia (Wenallt) workings of Cadoxton, and Mynydd March Hywell, nor can there be a large displacement if any between the Wenallt outcrops on the north and south sides of the Neath Valley. We are compelled to assume therefore that the Gnoll Fault must continue to head westwards so as to keep clear of the southernmost workings in the Gellia Vein, and must run into the Rhydding Fault. The bend is unusually abrupt for so large a fault, but can be matched to a certain extent both in the Rhydding and Dyffryn Faults further north. Moreover, it is a fact that the Rhydding Fault greatly increases in its throw at Cadoxton, as would happen if it had been joined by another large westerly downthrow, a fact, however, which is capable of another explanation.

The Rhydding Fault.—This fault is recognisable in the South Crop near Baglan House, and becomes an important downthrow to the west near Neath, its throw at Eaglesbush amounting to 140 yards. Near Cadoxton on the north side of the Neath Valley, it throws the Wernffraith Seam nearly on a level with the Gellia, which means a displacement of about 500 yards, *i.e.*, an increase in throw of 360 yards in about a mile and a half. Two miles further north the throw increases to nearly 800 yards, but at Cwm Clic, nearly five miles north of Cadoxton, the fault throws No. 1 Rhondda on a level with the Graigola, which means a displacement of only about 340 yards. Thence the dislocation runs northwards and probably becomes the Bryn

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Lleffrith Fault previously mentioned. Two facts may be noted with respect to this fault. Firstly, it splits near Letty-sac so as to effect its throw by two steps; the easternmost step throwing in a small patch of the Graigola Vein (which is now being worked) on a level with the Gellia and being therefore about 240 yards, while the second step which lies between 300 and 400 yards further west, throws the Graigola down a further 500 yards, or more, to the position in which it has been worked at the Dyffryn Main Colliery. The second point is that the fault on approaching the Tawe Valley at Cwm Clic makes a sharp bend to the west, but after crossing the valley resumes its normal trend. The bend, though much less abrupt, resembles that made by the Gnoll Fault. S. Wales. (Mr. Strahan.)

The Dyffryn Fault, which runs nearly parallel to the Rhydding Fault, lies at an average distance of about a mile to the west of it. It is a downthrow to the east, and with the Rhydding Fault forms the well-marked trough of Dyffryn. It crosses the south crop on the west side of the Neath at Briton Ferry, and from Skewen can be traced northwards almost continuously both by old workings and on the surface past the Tawe Valley. This fault also on crossing that valley makes a bend similar to that made by the Rhydding Fault. At Skewen the Dyffryn Fault throws the Greenway down nearly on a level with the Graigola Seam, and may be taken to be a shift of 100 yards; near Dyffryn House it is believed to have a throw of 380 yards and at Wernddu of 440 yards, the Graigola of the west side being at a higher elevation than the Bryn Coch Vein of the east side. Here the fault is at its maximum, for near the Tawe Valley it throws the Graigola on the east a short distance only below the Hughes Vein on the West, a shift of less than 300 yards. Both here and at Llangiwg, however, it is accompanied by strong flexure which makes it difficult to estimate the shift effected by the fracture alone.

It will be seen that the Rhydding and Dyffryn Faults attain their maxima in the same region, namely near Bryn Coch; the measures dropped down in the trough between the two faults assume in fact a synclinal form, the deepest part lying at the spot named. The strata composing Mynydd March Hywell on the east side of the Rhydding Fault show no such synclinal structure, and the increase in the throw of the Rhydding Fault from Neath northwards is thought by some authorities to be sufficiently explained by the difference in inclination of the strata on its two sides, without the assistance of the Gnoll Fault, as discussed above. The supposition appears to involve a confusion between cause and effect; the synclinal form of the trough measures is the necessary result of so large a subsidence between two fractures of limited length.

The Gardener's Fault.—This important westerly downthrow runs from Jersey Marine by Glan-y-wern and up the Crymlyn Dingle. Here it throws the Llansamlet Four Foot Vein on a level with the Maes Melyn Vein. The Four Foot Vein we believe to be the Wernffraith, which lies 236 yards above the

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S. Wales. (Mr. Strahan.)

Graigola at Llansamlet, while the Maes Melyn lies about 87 yards below that vein, the throw of the fault therefore being 323 yards. The fault intersects the outcrop of the Graigola at the old Heol-ddu Colliery, and passes through the Birchgrove and Sister's Pits to Glais, whence its course is still under investigation.

The Brother's Fault.—This may be regarded as a branch of the Gardener's Fault. springing from it between Heol-ddu Drift and the Emily Pit. At the Brother's Pit it was found to consist of three steps of 40, 50, and 60 yards, all down to the west. It appears to have been touched from the Garth Pit and to range for the Midland Railway bridge at Clydach.

The Bethel or Parc Pit Fault.—This is also a downthrow to the west, and has been traced at present through Pentre-dwr, the New Pit and the Parc Pit at Trallwyn to the Gwern Pit. Here its throw is said to be 100 yards. The fault has been touched also in the workings both of the Drew's and Four Feet Seams from Brother's Pit, but its throw has not been determined, though it seems to be diminishing northwards. What may be a continuation of it was touched 200 yards south-west of the Garth Pit.

The Six Pit Fault traverses the pit of that name and the Marsh Pit, and is a downthrow to the west.

The Pwll Mawr Fault is a downthrow to the east of 80 yards at the Pwll Mawr Colliery, but is supposed to be rather less south of Bon-y-Maen. Its effects on the configuration of the ground are most marked, however, where it crosses the outcrops of the Hughes group of veins at Tir-isaf, and throws the soft measures associated with them against the Pennant of Carn Nicholas Farm. The fault runs out to sea at the Crown Spelter Works.

TRIASSIC.

As already mentioned, various tracts of formations younger than the Carboniferous series have been revised in connection with the resurvey of the Coal-fields, so that the one-inch sheets might be everywhere brought up to date. In North Staffordshire and the surrounding country this revision has been carried on by MESSRS. BARROW, GIBSON, POCOCK, and WEDD. In South Wales the work has been mainly done by MR. TIDDEMAN and MR. CANTRILL.

North Staffordshire Region.

In North Staffordshire MR. BARROW has mapped two separate areas of Bunter Sandstone and Conglomerate. The first of these lies to the north of Leek, and forms the north end of the long inlier that fills the old pre-Triassic valley through which the Churnet now flows. This valley has been eroded in the mass of soft shales underlying the Third Grit. In shape it recalls the

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form of some of the longer lakes of Scotland, from which, however, it essentially differs in that the water must have flowed out through the breaching of one side of the valley. This outflow not improbably occurred at the hollow south-west of Rudyard, as is suggested by the occurrence of the patch of Bunter at Endon, some miles down this lateral valley.

In the other or Cheadle area of Triassic rocks only their margins have been at present mapped, so that little can yet be said regarding them. Evidence has been accumulated as to the very uneven nature of the surface of the Carboniferous floor on which the Bunter strata rest. Thus, the mass of New Red Sandstone on the north side of Cheadle, shown on the published map as an outlier, resting apparently on a comparatively flat surface of Coal-measures, proves to be in reality merely the end of a thick mass that fills an old, steep-sided valley. This mass and the valley which it fills is continuous eastward to the Churnet valley, in which direction the water flowed. The breadth of this sandstone at Cheadle arises from the valley having here been cut out of soft shales. Further east the valley passes through the much harder Kingsley rock already referred to, and there, together with its infilling Bunter Sandstone, it becomes much narrower. This connection of the Cheadle outcrop with the main mass to the east is of considerable practical importance to the town of Cheadle, for instead of their water supply being obtained from a catchment area of only one square mile, it in reality taps the water that is accumulated in the great mass of sandstone to the south-east. The supply will thus be more than enough for the town for many years to come. Cheadle District. (Mr. Barrow.)

To the west of Cheadle and in a direct line with the old valley just referred to, another ancient hollow existed which drained westward, and has likewise been filled up with Bunter Sandstone Its position is indicated on the map by the tongue that projects eastward from the main outcrop of that rock. The coincidence in direction of these two valleys suggests a common origin for them. The southern end and side, and in some cases the northern, correspond approximately with a rather large fault in the Carboniferous rocks, whereby the position of the valley was probably determined. This influence on the topography dates from a time anterior to the deposition of Bunter strata, as the mining evidence clearly proves. While the Two Yard Coal has been met with on the upthrow side of the fault under the Bunter Sandstones, it does not exist in the bottom of the old valley, even although it has been thrown down 25 yards. After its dislocation and subsidence, this coal-seam was obviously eroded out of the bottom of the valley before the red sandstone was deposited. It has been further ascertained that when a small easterly or westerly projection of the Bunter Sandstone is met with, it fills a small steep-sided pre-Triassic valley, whether or not a fault may there traverse the Carboniferous rocks.

Nearly all the faults in the Cheadle coal-field are of pre-Triassic age; they all trend either due east and west, or north and south. No such faults have been met with in the Bunter

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series in this area. There are, however, a few faults in the red rocks. They are, in the main, parallel to the trend of the steep-sided old valleys. The absence of any such faults in the Coal-measures, so far as known, raises the question as to what extent these faults cut the Carboniferous rocks, or are restricted to the overlying Red Sandstones. It seems probable that the latter supposition is really true in at least a number of instances. The pitting of the pebbles in the conglomerate shows that a great amount of compression has taken place, and these faults may represent the subsidence upon contraction of the incoherent sands into the deep and steep-sided valleys. They may thus have been quite superficial movements.

Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

Considerable difficulty has been experienced in establishing satisfactory divisions for the Trias in the Stoke district. The Keuper basement-beds are not sharply marked off from the underlying Bunter division and overlying Waterstones, and the latter graduate up into the Red Marls. It is doubtful, indeed, if the basement-beds are really represented there. Three divisions can be roughly made out. The lowest constitutes the Bunter group, consisting of red false-bedded sandstones and pebbly sandstones, with bands of shingle at several horizons; the middle includes even-bedded brown and white sandstones passing up into thin flaggy, thin-bedded sandstones with marl; the upper consists of red marl, with occasional thin bands of white and red flags, (skerries).

In the tract round Fulford Mr. Pocock has found the Trias subdivisions to be feebly represented. Not only are the Upper and Lower Mottled Sandstones absent there, but the Keuper Sandstones, which form the dominant features of the landscape in the Cheshire hills, occupy a subordinate position along the flanks of the plateau of Bunter Conglomerate, nor is there any clear division between the basement sandstones and the Waterstones. Thin sandstones of the waterstone-type are found interstratified with the coarser basement-sandstones, and though they are more common in the upper part of this division, it is not practicable to separate them on the map.

The Keuper Sandstones extend for about a mile south of Fulford, but in the Hilderstone valley they are absent and the Keuper Marl rests directly on Bunter Conglomerate. In the Triassic areas surveyed by Mr. Wedd, between Market Drayton and Betley, the same difficulty has been encountered in accurately subdividing the Trias. The broad divisions of Bunter, Keuper building-stones, flaggy waterstones and red marl can be recognised. The red marl passes downwards by a gradual increase of sandy material into flaggy waterstones These, again, in their lower part alternate with, and perhaps pass laterally into, soft false-bedded red sandstones and harder coarse white and brown building-stones, which are even-bedded in the west of the district, but are often markedly false-bedded at Blythe Bridge in the east. They sometimes contain a few pebbles, and it is often difficult to separate them from the Bunter group. This group in the ground mapped last year consists, as elsewhere, of red sandstone and

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pebble-beds, but it is uncertain whether these two types occupy separate horizons. At Merelake Hall, near Alsager, the Bunter group contains a considerable quantity of barium-sulphate as a cement, and narrow veins of baryto-celestite also occur. Barium is frequently found in the Keuper Sandstones of the western part of the district. Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

At Linleywood, near Talke, a small triangular patch has been represented as Coal-measures upon the published map, on the down throw side of the Red-Rock-fault, two faults being introduced to account for its unusual position. This patch, however, seems to be really Keuper Sandstone. It closely resembles the Keuper Sandstone of Beeston Castle in Cheshire, and that of Bearstone, near Norton in Hales. The rock seen in Linleywood passes up into red flaggy sandstones, and on the same strike in an adjoining field red flaggy waterstones are exposed. Moreover, a minimum thickness of some 400 feet of Bunter strata has been proved in the workings of Bunkers Hill Colliery only about 200 or 300 yards to the south-west.

South Wales.

Of the eastern half of the broad tract of Secondary Rocks which extends from Cardiff to Porthcawl some account has been given in previous reports of the work of the Survey.* The western half has now been completed by Mr. Tiddeman and Mr. Cantrill, under the supervision of Mr. Strahan, who, from the reports supplied by his colleagues and from his own notes, has supplied the following general statement:—

The description of the Secondary Rocks extending from Cowbridge to Pyle was held over last year until the examination of the whole tract had been completed. All the strata in this part of the region, especially the Rhætic, assume so abnormal an aspect and change so rapidly in lithological character that only by continuous mapping could the change be realised and the stratigraphical horizons be identified. The eastern part of the district was surveyed by Mr. Cantrill, and the ground from Pen-llin westwards by Mr. Tiddeman. In company with these two officers a complete traverse of the district was made by Mr. Woodward and Mr. Strahan for the purpose of checking as far as possible the correctness of the identification of the Rhætic strata in their abnormal form.

Triassic and Rhætic.—The Triassic conglomerate at Llanharry was found by Mr. Cantrill to lie unconformably upon Carboniferous Limestone, Millstone Grit, and Coal-measures. It seems to be of Upper Keuper age, and earlier than the uppermost green marls. It usually consists of a mass of pebbles of Carboniferous Limestone (ranging up to two feet in length), chert, and grit possibly derived from the Old Red Sandstone. These

* *Annual Report* for 1896, pp. 66–68: *Summary of Progress* for 1897, pp. 125, 126; *Id.* for 1898, p. 138.

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materials are embedded in a ferruginous calcareous matrix in which iron occasionally so far predominates as to yield an ore which has been extensively worked.

It has been shown in previous *Reports* that all horizons of the Keuper Marl assume a littoral character in one place or another. At Penarth there is a considerable thickness of normal red marl, at the base only of which any conglomerate occurs; at Pendoylan the upper part also becomes littoral, while at Bonvilston, Llantrithyd, and St. Hilary the overlying green marls also pass into breccias. At Llandough the lower parts of the Triassic breccia are red, while the upper are yellow and evidently belong to the time of the green marls. In spite of these repeated evidences of the neighbourhood of a shore-line, the Keuper Marls on the whole preserve their typical aspect as far west as they extend. The green marls are well shown in a clay-pit near Pencoed, three miles north-east of Bridgend, behind the Old Pyle Inn, and to the south and south-west of Pyle Station. In these sections they present no essential difference from the green marls of the Penarth region, though the Rhætic strata above them have assumed a totally new aspect.

Rhætic Beds.

South Wales. (Messrs. Tiddeman and Cantrill.)

The remarkable change which affects the Rhætic strata between Cowbridge and Pyle consists in the replacement of shales by sandstones and coarse grits, together with some increase in thickness. The thin group of soft shales and thin limestones which constitutes the formation at Penarth passes gradually into a massive rock which occasionally produces a moorland scenery rivalling that of the Millstone Grit. The change sets in near Cowbridge, but it is more fully developed near Bridgend and Pyle in the area surveyed by Mr. Tiddeman. Its first appearance in the neighbourhood of Cowbridge is thus described by Mr. Cantrill:—

The lithological type as presented by the Rhætic rocks at Penarth persists for some ten miles westwards. At several points, even where they overlap the Keuper and rest directly upon the Carboniferous Limestone, the black *Avicula*-shales and the White Lias preserve their normal aspect, and manifest none of the signs of littoral deposition which usually characterise the Keuper under such conditions. Thus a roadside section near Bonvilston shows clays and thin *Pecten*-limestones resting directly on the Limestone.

Two railway-cuttings near St. Mary Church Road Station reveal a few feet of the upper Rhætic strata under the *Ostrea*-beds of the Lias. One bed, which is exposed for eight feet, is oolitic, an unusual feature in Rhætic limestone, and one not previously observed. In the cutting south of Cowbridge Station, limestones of Rhætic age, but not richly fossiliferous, with a few inches of breccia, probably of Keuper age, rest unconformably upon Carboniferous Limestone. They are overlain by a very

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hard Liassic limestone, containing bands of the shelly rock known as Sutton Stone, which seems to be a modified representative of the *Ostrea*-beds. South Wales. (Messrs. Tiddeman and Cantrill.)

At Tregyff, near Llantrithyd, the sandy type of Rhætic first appears. The *Avicula contorta* series is there represented by blue sandy marls with *Pecten*-limestone and a conglomerate containing pebbles of Carboniferous Limestone and chert, overlying sandstone with casts of *Cardium* and *Avicula contorta*. Similar sandstones prevail north of Tregyff and are associated with bands of limestone composed of shell-fragments and resembling the Sutton Stone variety of the Lias. The proportion of sandy material increases northwards towards the Carboniferous ground, and the Rhætic sandstones have been quarried near Cowbridge, at St. Hilary, and at Llandough.

At Pencoed, from which point westwards this account is founded mainly on notes by Mr. Tiddeman, the Rhætic sandstones are let down between two faults. They are extensively worked for building, and have been used for silica firebricks. The rock is a rather fine freestone, white but with bands of a light greenish hue. *Pullastra arenicola* and scales of *Gyrolepis Alberti* have been collected from this sandstone. The presence of these fossils taken in connection with their superposition upon the uppermost green Keuper Marls exposed in characteristic form close by, as mentioned above, proves that the rocks belong to the *Avicula contorta* zone.

Near the top of the hill of Coed Mwstwr there is a small faulted outlier of this sandstone, together with yellow and green limestone-conglomerate which may represent the green marls under shore-conditions.

In approaching St. Mary Hill from Coychurch we pass over in descending order the *Ostrea*-beds of the Lower Lias, some compact limestone, which no doubt represents the Cotham Stone, some green marls with what appears to be an interbedded red marl, Rhætic sandstone, a space probably marking the outcrop of the Keuper green marls, and Keuper conglomerate. The sandstone at the brow of the hill has yielded to Mr. Tiddeman obscure casts of mollusca and scales of *Gyrolepis Alberti*. St. Mary Hill Down, which is covered with huge blocks of Rhætic sandstone, is formed by a compound anticline, much broken by strike-faults. Towards the south, where the sandstone dips away to the lower ground, the edge of the moor is followed by a depression, probably marking the outcrop of the upper part of the Rhætic group, and this by an escarpment of the *Ostrea*-beds of the Lias. These beds, however, are not quite of their usual type, and close by pass into a beach of shore-deposits.

In Coity a road-section west of the Castle exposes alternations of these sandstones and shales with greenish colouring and a little red mottling. The strata at first sight much resemble Keuper, but yield *Modiola minima* in abundance, a fossil which is plentiful in the upper part of the Rhætic group.

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South Wales. (Mr. Tiddeman.)

In the well-known Quarella quarries, where a white and pale-green building-stone is obtained, MR. TIDDEMAN has noted the following section:—

		Ft.	in.
	Blue limestone, with *Ostrea liassica* - -	0	2
Rhætic Beds	Clayey limestone, representing the Cotham Stone, variable.		
	Grey and green clay, with variable calcareous bands. *Lima* sp. - - - - - -	2	6
	White and pale-green sandstone, seen to -	35	0

The same rock was formerly quarried near the Angeltown Asylum, and Rhætic fossils may be obtained in the quarry rubbish.

The railway-section at Cwrt Coleman, which was described in detail by MR. TAWNEY in 1865,* is now partly obscured, but some of the beds, to which he refers as containing fish-remains on the south side, can now be seen on the north side of the line. A field-road south of Melin Cwcw shows a succession differing somewhat from that in the railway. We here obtain in descending order:—

	Blue limestone with *Ostrea liassica*, *Pleuromya crowcombeia*, and a coral.
Rhætic Beds	Buff marlstone, weathering white, probably representing the Cotham Stone.
	Green marls with a band of red marl, closely resembling Keuper Marl.
	Calcareous sandstone, several feet thick.
	Tough tufaceous limestone.

The strata exposed in the railway-cutting on the north side of the line evidently rise from below these, and themselves rest upon the thick Rhætic sandstone which forms the crest of the hill of Cwrt Coleman. The road-section therefore confirms the observation made in Coity that there is red and green marl associated with the upper part of the Rhætic group.

Higher up the valley some old pits show black shales resting on green limestone and white marly limestone. The green limestone is full of shells, which however cannot be broken out, but there is little doubt that the strata belong to the upper part of the Rhætic series.

The "Pyle Inn" quarry, which has been opened of late years to get stone for railway-viaducts, &c., gives the following sections:—

	Ft.	in.
Sandstone with *Natica pylensis*, *Cylindrites oviformis*, *Myophoria* - - - - -	12	0
Ochreous bed - - - - - - - - -	0	4
Fine sand - - - - - - - - -	1	3
Green and grey clay - - - - - - -	3	6
Calcareous nodular bed, *Acrodus minimus* -	0	3
Shales - - - - - - - - - -	1	3
Calcareous nodular bed, with fish-remains - -	0	3
Shales - - - - - - - - - -	1	8
Fine whitish sandstone, with plants and at top a seam of quartz pebbles, with remains of *Hybodus* and *Acrodus*, seen to - - -	12	0

* *Quart. Journ. Geol. Soc.*, vol. xxii., p. 70.

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The slopes below expose characteristic Keuper green marls. South Wales. (Mr. Tiddeman.)

The Rhætic sandstone has also been much quarried west of Pyle Church, the outcrop being followed for a considerable distance. Near the entrance to the quarries a white sandstone is seen with casts of *Pullastra arenicola* near its base. Above it was a band of green and red marl of typical Keuper aspect. Further on in the quarry the sandstone, where it has been more lately worked, shows bright green marly partings with ripplemarks, and yields *Anatina præcursor, Myophoria, Axinus cloacina,* while *Natica* has been obtained from the quarry-rubbish. The occurrence of the red and green marls next above this sandstone suggests that that rock lies high in the Rhætic group, and probably corresponds to the upper of the two sandstones in the "Pyle Inn" quarry, which also yielded *Natica*, etc.

Of the many scattered openings on Stormy Down the greater number have been made in search of sand for silica-bricks. One of these, lying south-west of the works, shows about 20 feet of massive sandstone, much like a Carboniferous sandstone, but resting on and containing thin seams of green clay. A little further west a swallow-hole shows that below it lies a limestone devoid of organisms and apparently of chemical origin, which is probably Keuper. The sandstone is thought by MR. TIDDEMAN to represent the lower sandstone of the "Pyle Inn" quarry. Further east, sandstones with green and yellow clays are exposed in a long line of excavations. They are occasionally green and ripple-marked, and yield casts of *Avicula contorta.* These probably represent the upper sandstone of "Pyle Inn" quarry.

The "Little Cement Quarry" on the edge of the Down, south-south-east of the Stormy works, shows a bed of shelly white limestone, resembling those seen in the old Rhætic pits west of Cwrt Coleman. From the material thrown out in deepening a spring close by, MR. TIDDEMAN obtained *Natica pylensis, Myophoria* sp., and *Cylindrites oviformis.*

The thick Rhætic sandstones form an escarpment of coarse white and yellow conglomerate near the top of Stormy Down. On some of the big blocks casts of lamellibranchs may be seen, but in other respects the stone might be taken for Millstone Grit. Such blocks are scattered all across the Down, and it was in one of these that the jaw of *Zanclodon cambrensis* was discovered.* It can now be stated with confidence that the *Zanclodon* occurred in true Rhætic strata of the zone of *Avicula contorta.*

In reference to the sections above described, MR. TIDDEMAN remarks that two points will strike anyone familiar with the typical aspects of Rhætic rocks in this country. One is the great preponderance of sandstone, the other is the occurrence of red beds above the sandstones, a colour which it is usual to associate with the Keuper Marl. From the abundance of sandstone he infers that the sediment was derived from a near source, probably the

* *Summary of Progress* for 1898, p. 202. See also E. T. NEWTON, *Quart. Journ. Geol. Soc.*, vol. liv., p. 646.

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South Wales. (Mr. Tiddeman.)

sandstones of the Carboniferous or even of the Old Red Sandstone, while the remains of plants in them, and of land-reptiles such as the *Zanclodon*, to which we may perhaps add ganoid fishes, all point to an estuarine origin. The red beds suggest a land-locked area in which copious evaporation and chemical precipitation could go on. The silting up of an estuary might furnish some of the conditions necessary for the deposition of strata of this nature. The evidence shows that in the area around Bridgend in Glamorganshire, the Rhætic beds are intimately linked with the Keuper Marls. They exhibit, in fact, a local recurrence of the sedimentary conditions which attended the deposition of the Keuper Marls.

Mr. Tiddeman believes further that it is not altogether impossible to recognise some of the limits of such an estuary as that in which these deposits may have been laid down. One fairly defined shore may be recognised at St. Mary Hill Down. It is generally, though not invariably, the case that where the upper Rhætic beds have been deposited, a normal succession can be traced up into the Lias, but that where the Lias is conglomeratic no Rhætic strata lie below. The presence of conglomerates in the Lias thus furnishes a clue to the original limits of the Rhætic area. Another point on the south side of the estuary can be fixed between Tythegston and Merthyr Mawr, where the Lias overlaps the Rhætic formation, and rests as a shore-deposit upon Carboniferous Limestone. The northern shore of the estuary is obscured by faulting, but the high ground of the Coal-field must certainly have formed an extreme limit in that direction. Near the southern side of the supposed estuary Mr. Tiddeman notes that shell-banks, calcareous tufas, and sandstones permeated by carbonate of lime occur at points which are almost certainly near what were shores of Carboniferous Limestone. Coarse grits and sandstones containing quartz-pebbles prevail in the Rhætic series, near where the Millstone Grit no doubt forms the underlying rock.

Isle of Skye.

In the *Annual Report of the Geological Survey* for the year 1896 some particulars were given of the Passage-beds, which occur between the Lower Lias and the New Red rocks in Skye and Raasay. In Skye the strata, which comprise some six or eight feet of calcareous sandstones, limestones, and micaceous shales, are exposed in situations rather difficult of access, in the banks of Allt a' Mhuilinn, south-west of Broadford Free Church, at the cascade of Allt an Daraich, on the eastern side of Heast, and on the foreshore at Lusa (Lussay). These Passage-beds have been regarded by Mr. H. B. Woodward as the only portion of the Secondary series of this region likely to be of Rhætic age, but he failed to find any recognizable fossils in them in Skye and Raasay, or at Applecross, in Ross-shire, where similar strata occur. Last summer Messrs. A. Macconо-

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CHIE and DAVID TAIT were instructed to make a diligent search for fossils at the above-mentioned localities in Skye, and they were rewarded by the discovery of a number of fossils, which have been submitted to MR. E. T. NEWTON and DR. F. L. KITCHIN.

At Ob Lusa, about eight feet beneath the famous coral-bed, which rests on a band of *Ostrea*-limestone (Lower Lias), there were obtained *Pleuromya? Nerita?* and *Cerithium cf. semele*, d'Orb. At Heast there were found some doubtful plant remains, together with *Ostrea*, *Mytilus*, and a fish-scale. At Allt a' Mhuilinn a number of Lamellibranchs were found, some of which closely resemble the Rhætic form *Myacites Escheri*, figured by Dumortier.*

The fossils are poorly preserved and crushed, so that they cannot be satisfactorily determined. In the opinion of both MR. NEWTON and DR. KITCHIN all the forms are such as might be expected to occur in the Rhætic Beds, and MR. WOODWARD, who has collected from the Rhætic Beds in many localities, is of the same opinion.

Isle of Arran.†

The most important observation recently made by the Geological Survey in Scotland is the discovery of fossils of Rhætic age in a streamlet about a quarter of a mile to the north-east of Derenenach, above the String Road, five miles to the south-west of Brodick in the Island of Arran. The rocks there have been mapped by MR. GUNN, who found them to be considerably disturbed. It was at first thought that they might belong to some part of the Old Red Sandstone. But eventually MR. MACCONOCHIE found in them a series of fossils which left no doubt that some of them are Rhætic. The specimens were first submitted to MR. PEACH, who recognised such characteristic forms as *Avicula contorta*, *Pecten valoniensis*, and *Cardium rhæticum*. They were subsequently placed in the hands of MR. E. T. NEWTON, who has supplied the following note regarding them:—

Avicula contorta, Portl. Several specimens clearly referable to this species leave no doubt as to the beds from which they came being of Rhætic age.

Pecten valoniensis, Defr. Two or three fairly good specimens agree with the shells from Rhætic beds, which have been called *P. valoniensis*.

Schizodus (*Axinus*) *cloacinus*, Quenst. One or two examples of shells with a sharp posterior keel are believed to be this species.

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* *Études Pal. sur les dépots Jurassiques du Bassin du Rhone*, 1864, Plate I., figs. 5 and 6.

† The discovery of the fossils was made after this *Summary of Progress* had been sent to the printer. Subsequently as these pages were passing through the press, Mr. Peach and Mr. Gunn ascertained that the strata containing the Rhætic fossils are not *in situ*, but are enclosed in a coarse conglomerate that fills a volcanic vent, probably of Tertiary age. The same observers also found masses of limestone containing Lias fossils and fragments of chert containing *Foraminifera* which may possibly be Cretaceous.

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Protocardium philippianum? Dunker (=*P. rhæticum*). There are two or three specimens which are in all probability *P. philippianum*, but none are so perfect as to make their identity certain.

Modiola minima? Sow. (=*minuta*, Goldf.). A specimen about ¾ in. long is referred to this species with some doubt.

Estheria minuta? Goldf. An imperfectly preserved impression of an oval shell may perhaps be this form, but it is very uncertain.

Gyrolepis Alberti? Ag. A broken fish scale showing a few ridges may be provisionally referred to this species.

The lithological characters of the strata containing the Rhætic fossils resemble those which are so persistent at the top of the Triassic system all through England and Wales. The red marls recall the well-known marls of the Keuper group; the grey marls seem to come in here as they do in South Wales, immediately below the fossiliferous black shales; and the latter again, though somewhat hardened, closely correspond with the equivalent strata in the same region. Fragments of decayed limestone which occur in the agglomerate have yielded what appear to be Lower Lias forms. They are not well preserved, but MR. NEWTON believes that they probably include such characteristic forms as *Ammonites angulatus* (?), *Cerithium semele* (?), *Gryphea arcuata* (?), *Pentacrinus basaltiformis* (?), and *Ditrupa globiceps*.

The importance of this fresh discovery in Arran is at least twofold. In the first place it probably gives a definite stratigraphical horizon for the red rocks of the southern half of the island, suggesting, if it does not absolutely prove, that these strata, in at least their upper portions, belong to the Keuper group, and are probably all of Triassic age. In the second place, the intrusive igneous rocks which disrupt these strata, and which form only a part of the great system of bosses and sills in the southern half of Arran, are now proved to be post-Liassic, or even post-Cretaceous, if the cherts should eventually prove to contain Cretaceous *Foraminifera*. Thus a further interesting and valuable piece of evidence is obtained to prove the comparatively late date of the younger igneous rocks of Arran.

JURASSIC.

Leicestershire and Rutland.

Hallaton and Burrow-on-the-Hill. (Mr. Fox Strangways).

The only tract of Jurassic rocks which has come within the range of the field-work of the Survey during 1899 lies to the east of the town of Leicester, on the borders of Leicestershire and Rutland, where MR. FOX STRANGWAYS has pushed the mapping eastward, so as to complete Sheet 156 (new series of the one-inch map). The district which he has so far completed lies between Burrow-on-the-Hill and Hallaton. It consists mainly of Upper and Middle Lias, with here and there thin coverings of Drift, which in a few places attain considerable importance. This part of the country was originally surveyed by PROFESSOR JUDD, but its revision on the six-inch scale allows considerably more detail to be put on

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the maps, and shows that the boundaries that have been drawn on Sheet 64 (old series) are merely approximate. The chief alterations to the published map, so far as the revision has advanced, appear to be at Skeffington and Noseley, where the Middle Lias has been found to extend much further than was supposed. In the first case, the Middle Lias probably stretches along all the high ground from Tugby to Skeffington, as strata of this age have been found at the latter village. It is not seen in the intermediate area owing to the thick covering of Drift. On the western side of the large valley between Goadby and Noseley an extensive outlier of Middle Lias was entirely overlooked in the former survey. This mass probably reaches from Noseley to the west side of Illston, and thence north to the fault at Billesdon, but its component strata are only seen at Rolleston and Illston, the rest of the ground being thickly covered with Drift. This western extension of the Middle Lias somewhat modifies the published view as to the size of the Billesdon Fault,* which is probably not nearly as large as was supposed. Although there seems to be an east and west fault there, it is probably not of any great magnitude. The outcrop of the Middle Lias south of Goadby is also incorrectly shown on Sheet 64, the Drift not being nearly so thick as the map would lead one to suppose.

Hallaton and Burrow-on-the-Hill. (Mr. Fox Strangways.)

The principal topographical feature that attracts notice in this district is the striking tabular forms assumed by the Middle Lias and Inferior Oolite over all the country from Somerby to Billesdon. Further south the Middle Lias becomes much thinner, and except at Goadby, it is only obscurely seen peeping out here and there from beneath the Drift.

CRETACEOUS.

Hampshire, Wiltshire, and Dorset.

In the counties of Hants, Wilts, and Dorset a small Cretaceous area has been examined by MESSRS. REID and DIXON, but the whole of the Chalk within it belongs to the Upper division, and is similar to that found in the surrounding country. Though much of the upper part of the Chalk is missing in the Cranborne district, represented on Map 314, there is no clear evidence of irregular folding or tilting before the deposition of the Eocene strata. In the absence of marked beds it is difficult, however, to speak with confidence on this point, especially as the junction of the Chalk and Tertiary formations is usually much "piped" as well as eroded.

Sussex.

For the purpose of securing the early completion of Sheet 317, which embraces the district between Petworth and Chichester,

Midhurst District. (Mr. G. W. Lamplugh.)

* Geology of Rutland, *Mem. Geol. Survey*, p. 66.

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Midhurst District. (Mr. G. W. Lamplugh.)

the mapping of the Cretaceous rocks was assigned to MR. LAMPLUGH, who, during the summer and autumn, carried forward the revision from the margin of the ground previously mapped by MR. HAWKINS, two miles west of Midhurst, eastward to the transverse valley of the Arun at Pulborough. The strata above the Upper Greensand had already been surveyed by MR. CLEMENT REID, so that the work consisted in tracing on the six-inch Map the outcrops of the various divisions of the Lower Greensand, Gault and Upper Greensand, together with the superficial deposits by which they are in places overlain.

According to the classification of the original Survey Map, the uppermost portion of the clayey deposits which occur immediately beneath the Lower Greensand escarpment is supposed to represent the Atherfield Clay, though definite evidence on this point is rarely forthcoming. A few marine fossils were, however, found long ago in nodules from this clay at the brickyard at Harwood's Green, near Pulborough, which serve to differentiate it at this locality from the underlying Weald Clay of fresh-water origin; and MR. LAMPLUGH obtained some specimens from this place.

There are occasional indications that the clay becomes interstratified with silt and fine sand towards its junction with the overlying Hythe Beds, and that in passing southward the base of the latter strata may contain an increasing proportion of clay.

The broader grounds for the classification of the Lower Greensand into the supposed equivalents of the Hythe Beds, Sandgate Beds, and Folkestone Beds of East Kent, are readily grasped in this part of West Sussex, though the exact boundaries of the sub-divisions are usually more or less vague, seeing that they rest entirely upon lithological differences which are subject to much local variation. The Hythe Beds are characterized, as in Kent, by irregular calcareous stone-bands among half-indurated loamy glauconitic sand, with the local development of impersistent layers or concretions of chert. The calcareous sandstone has been much used for building, and the chert is extensively dug for road-mending.

The Sandgate Beds are variable in composition, but contain more clay and silt than the underlying and overlying divisions. In the western part of the district a thick bed of sand, near the base of this series, is partly composed of smooth polished grains of brown iron-ore. It has been suggested that this ferruginous sand might be of some economic value, but the average percentage of iron (23) is probably too low to bear the cost of carriage. The iron-sand disappears rather suddenly at a short distance to the eastward of Selham. The Sandgate Beds are for the most part destitute of fossils, but MR. LAMPLUGH found a richly fossiliferous band, consisting of ironstone crowded with the casts of marine shells, at the top of the iron-sand, in two apparently new localities near Midhurst (June Lane, and the river bank due south of Cowdray Ruins). In the stream-bed east of Ambersham Common, the same observer collected from a thin band of sandstone some plant remains, including traces of *Weichselia*.

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Midhurst District. (Mr. G. W. Lamplugh.)

The Folkestone Beds consist of sharp sand, strongly current-bedded, with ironstone concretions and thin partings of pipe-clay. Excepting the cast of a fragment of wood with teredo-like borings, no organic remains were found in these sands. At the top of this division, immediately below the Gault, the sand is indurated into a hard grit-band, from two to four inches thick, of a deep red colour, which is persistent throughout the area examined.

The Gault and Upper Greensand maintain the same character as in the country farther westward, and require no especial comment here. A few fragments of Ammonites, apparently *A. interruptus*, were collected in a brickyard in the Gault at Pitsham, near Midhurst, and the same species was also found in a new brickyard at Hardham. Both sections would probably yield better specimens if examined during the excavation of fresh clay.

Among the fossils collected by Mr. Lamplugh during last season's work the following have been named in the Palæontological Department of the Survey by Mr. E. T. Newton and Dr. F. L. Kitchin:—

June Lane, Midhurst, Sussex. (Sandy Ironstone; Sandgate Beds.)

Cardium ?
Corbula striatula ? Sow.
Cytherœa ?
Nuculana scapha, d'Orb.
Tellina (Linearia), cf. concentrica, d'Orb.
Actæon sp.
Aporrhais sp.
Trochus ?

Cowdray Ruins (River Bank due South of). (Sandy Ironstone; Sandgate Beds.)

Cucullæa sp.
Exogyra sinuata ? Sow.
Nuculana sp.
Trigonia sp. (of the group "Scabræ").
Actæon sp.
Cerithium ?
Trochus sp.

Stream-bed South-East side of Ambersham Common, 200 Yards North-East of Hoyle Farm. (Sandgate Beds.)

Cf. Weichselia Mantelli, Brongn.

Harwood Green Brickyard, near Pulborough, Sussex. (Nodules, Atherfield Clay.)

Exogyra conica, Sow.
Pinna sp.
Thetis ?
Natica sp.

TERTIARY.

The revision of the Tertiary areas of the Hampshire and London Basins has been continued under the superintendence of Mr. Clement Reid.

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Hampshire Basin.

(Mr. Clement Reid and Mr. E. E. L. Dixon.)

With regard to the ground already reported as re-surveyed, considerable progress has been made in the reduction and publication of the revised maps. The sheet of the map (No. 315), showing the country around Southampton, has been engraved and published during the past year. Sheet 316 (Fareham) is partly engraved; but has been kept back to allow of the insertion of information obtained during the progress of a new railway. The memoir on sheet 328 (Dorchester) has been revised and published. Sheet 314 (Ringwood), which it was hoped could be completed and engraved during the year, was delayed owing to the unexpectedly late appointment of Mr. Dixon, who only commenced work in July; and also owing to necessity of Mr. Reid's presence at the office during part of the summer and again throughout December. The small area left over in this map (only about 14 square miles) will be finished early in the present year, and the map will then be sent to the engraver.

Hampshire has now been surveyed upon maps on the scale of six inches to a mile, with the exception of the north-east corner, around Aldershot. Half of Wiltshire has now been surveyed, mainly the eastern and south-eastern part. Dorset has advanced till about half the county has also been surveyed. In each of these counties the work of the past two years has consisted in completing and connecting scattered areas already partly mapped. The policy of completing defined areas will lead to the maps being more quickly available to the public, and ought to enable the work to be done more satisfactorily and more economically.

The recent field-work in the Hampshire Basin has been confined to the western border of the New Forest, the Avon Valley, and the adjoining parts of Dorset, all this ground being comprised in sheet 314. The area was almost entirely surveyed by Mr. Reid, who mapped the Forest, the Avon Valley, and part of the Chalk in Dorset. The newly appointed Assistant Geologist, Mr. E. E. L. Dixon, was placed under Mr. Reid's care, but as he only joined the staff in July, he could not contribute largely to the area of ground surveyed. He mapped the parts around Horton and Verwood. Much of Mr. Reid's time in the field was necessarily spent in training his new colleague.

The scientific results of the past season's work in the Hampshire Basin have not been striking; for the area on which Messrs. Reid and Dixon were engaged was surrounded on every side by ground already carefully revised. In Hampshire Mr. Reid found less than usual to alter in the Eocene boundaries of the published map (drawn by Joshua Trimmer), and though there were a good many points of scientific interest, not much of economic value was found. The principal novelties were, the discovery that the mass of pebbly gravel on Ashley Heath (west of Ringwood) was of Eocene age, and corresponded to the shingle seen in the cliff east of Bournemouth. The irregular appearance

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and disappearance of a mass of pebbles at the base of the marine Bracklesham Beds is not surprising; but it is noteworthy that on Ashley Heath this shingle is full of perfectly rounded pebbles of a peculiar siliceous sandstone, which corresponds exactly in its curiously waved bedding, and in the abundance of vertical root-cavities with the larger angular greywether blocks found loose, or in the Drift nearer to Salisbury Plain. In *Summaries* for previous years it has been shown that abundant evidence exists in the Hampshire Basin of an overlap westward and southward of the Reading Beds and of the Lower Bagshot group, till at last they rest on Palæozoic strata. We have now discovered evidence that the Bracklesham Beds also must overlap the lower horizons to a certain extent, for the pebbles of greywether must be derived from eroded strata of Reading age. A few fragments of Greensand-chert, which occur in the same pebble-bed, may have been derived from the chert-bearing fluviatile gravels of Bagshot or Reading age; they need not have been derived immediately from the Greensand. (Mr. Clement Reid and Mr. E. E. L. Dixon.)

New fossiliferous localities have been discovered in the Reading Beds, London Clay, Bagshot Sands, Bracklesham Beds, and Barton Clay; but within the area here alluded to fossils are badly preserved and not abundant. The most interesting change in the fossiliferous strata is the reappearance of a bed of marine fossils in the Woolwich and Reading series, this district being a long way from any other in which the Woolwich type, as distinguished from the Reading, is represented. The marine bed, already known through the labours of other observers, especially of Mr. Ernest Westlake, occurs at Rockbourne, and from that place extends south-westward through Wiltshire. It has also been discovered by Mr. Dixon at several new localities near Horton. The deposit is usually a glauconitic sand or loam, full of oysters, but containing little else. It now seems probable that the glauconitic loam without fossils, met with in the Dorchester sheet (No. 328) is a continuation of the same marine bed.

The Eocene deposits in the Dorset area surveyed last season are similar to those to the north-east and south-west. Mr. Dixon, as just mentioned, has discovered some new fossiliferous localities in the Reading series, though the fluviatile deposits of that age still remain barren. It is interesting to note, however, that subangular gravels containing Greensand-chert and fragments of Palæozoic rocks make their appearance as far north-east as Downton, though they are scarcely so angular as they become nearer Dorchester. Mr. Dixon has also obtained London Clay marine fossils at Verwood, and badly-preserved leaves in the Bagshot Sands not far from that place. He attempted to map out the clay-beds which often form marked features in the Bagshot series; but these proved to be as impersistent and irregular there as they are in other districts, and no one bed could be traced far. The clays dug around Verwood are not sufficiently good even for the coarse pottery there made, and the ware is consequently manufactured from the plastic clays of the Reading series, carted from other places.

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London Basin.

(Mr. Clement Reid and Mr. A. C. G. Cameron.) A considerable area in Middlesex has been surveyed by Mr. A. C. G. Cameron during the past season under Mr. Reid's supervision. The greater part of it is underlain by London Clay, seldom containing fossils, and of the ordinary type. During an inspection, however, of the Stanmore district, in company with Mr. Cameron, Mr. Reid was struck by the marked resemblance of the supposed "high-level Pleistocene gravel" to undoubted Eocene gravels in the Hampshire Basin, and to the pebble-beds exposed some years since at Highgate, in the grounds of St. Joseph's Retreat, and in the deep trench of the Steep-grade Tramway. The Highgate deposit certainly belongs to the top of the London Clay or to the base of the Bagshot Sands, and on closer examination it was found that the Stanmore gravel also presents all the characteristics of an Eocene deposit. Its flint-pebbles are nearly always well-rounded, they have undergone zonal alteration to the centre (Pleistocene alteration does not extend nearly so deep), and mingled with them are rare fragments of Greensand-chert, hard sandstone, black grit with quartz-veins, and a few quartz-pebbles. Their composition thus closely resembles that of Eocene gravels described in former *Summaries*.*

The unexpected result of this examination must lead to a reconsideration of the geological age of the whole of the supposed high-level Pleistocene gravels around London. It now seems doubtful whether outside the glaciated area any Plateau Gravels (*i.e.*, gravels more than about 150 feet above the Thames), are to be found that are not either of Eocene age, or derived wholly from Eocene deposits at a higher level. Stanmore is the highest hill (503 feet) in Middlesex, and dominates a considerable area down which the Eocene material has travelled.

Hungerford District. (Mr. J. H. Blake.) At the western end or apex of the London basin, some fresh information has been obtained by Mr. J. H. Blake as to the thickness of the Tertiary formations near Hungerford. It was derived from a boring made by Messrs. Callas, Sons, and May in July last, at Kirby House, about a mile and a quarter east of Inkpen, and nearly two miles and a-half south of Kintbury. From specimens and detailed information supplied to him during the progress of boring, and from inspection of the material brought up at the place, Mr. Blake was enabled to prove the occurrence and thickness of the following strata:—

	Feet.
Bagshot Beds	90
London Clay	52
Reading Beds	75
To Chalk	217
Chalk	103
	320

* See for example *Summary* for 1897, p. 130. *Annual Report* for 1895, p. 11.

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A well was dug to the depth of eleven feet, and the rest was bored. The clean-cut section of the well showed the Bagshot Beds to be well stratified, and to dip north at an angle of 26°. This steep inclination brings up the Upper Greensand from beneath the Chalk to form the "Shalbourn inlier," south-west of Inkpen, as shown on the Geological Survey Map. The information obtained by this boring, satisfactorily clears up what was previously obscure. The published maps show no Bagshot Beds at the site of this boring; the omission having perhaps arisen partly from a certain similarity of the variegated coloured sands and loams of the Bagshot Beds in this district, to those of the Reading Beds, and partly also from the absence of sections.

The Igneous Rocks of Skye.

The survey of the Tertiary igneous rocks of the Island of Skye has been continued by MR. HARKER, who has been engaged in the district of the Cuillin Hills and the surrounding parts of the great plateaux of basalt. He has prepared the following notes regarding his work of the past season. (Mr. A. Harker.)

The basaltic plateaux.—More than twenty square miles of the moorland country have been mapped, lying to the north-west, west, and south-west of the Cuillin Hills. The general nature of the ground is that of small plateaux or flat-topped hills, rarely reaching 1,500 feet above sea-level. The slopes are conspicuously terraced, the salient features being always due to the numerous hard intrusive sills intercalated among the softer lava-flows. The latter, in contrast with the sills, are in general amygdaloidal. The prevalent type is basalt not rich in olivine, graduating into rocks which might perhaps be more accurately styled augite-andesites, but no such discrimination has been found practicable in the field. Conspicuously porphyritic varieties occur in a few localities only, *e.g.*, below Coire Labain. Approaching the gabbro boundary at the foot of the mountains, the lavas become harder, in consequence of metamorphism, and, the intrusive sills at the same time dying out, the details of the surface-relief assume a new character.

The metamorphism imparts to the basaltic lavas a tougher consistency and a more splintery fracture. The attendant mineralogical changes are most evident in the amygdules, which here contain felspar (formed at the expense of zeolites), hornblende (from chloritic substances), quartz (from chalcedony), epidote, and other new-formed products.

Conglomerates, with subordinate banded tuffs, are interbedded among the basalts at several places on the slopes above Glenbrittle House and elsewhere, while breccias and agglomerates occur more frequently among those relics of the basalt group entangled in the gabbro of the mountains. The pebbles in the conglomerate are chiefly of Jurassic sandstones, well rounded, while basalt, gabbro, and granite occur more sparingly.

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Isle of Skye. (Mr. A. Harker.)

The only place where the base of the basalt group has been reached in the course of the season's mapping is along the coast facing the Isle of Soay. The underlying rocks are here for the most part Torridonian (Applecross grit). The base of the volcanic group, which is about 400 feet above sea-level at the western point of Loch Scavaig, sinks gradually westward to only a little above high tide at the outlet of Allt nan Leac, the stream draining Coir' a' Ghrundda. Here a small strip of Lias limestones is exposed on the shore, while the Trias conglomerate, rising from beneath these limestones, forms a small promontory 200 yards east of the mouth of the stream, as recorded last year.* Farther west the basalts come down below sea-level. There is another locality within the area mapped where the base of the volcanic group must be very near the surface, viz., on the shore of Loch Harport, near Carbost. Some years ago piles were sunk for a new pier about 500 yards beyond the Talisker Distillery, and the cores preserved in the yard of the distillery are of sandstone, presumably Jurassic. It is stated that the borings were only six or seven feet deep, under ten feet of water at low tide (about twenty-one feet at high tide).

The gabbro of the Cuillins with its associated patches of basaltic lavas.—The survey of the Cuillin Hills has been nearly completed during the past season by the mapping of some nine or ten square miles of the main (western) range, with its subsidiary spurs. The detailed study of this part of the ground has brought out more clearly the complexity of its structure, and especially the very considerable part played by portions of the basaltic lavas entangled in the gabbro and highly metamorphosed. These enclosed patches have lenticular or less regular forms, with dimensions ranging from a few yards to more than a mile. When their inclination can be detected, it is usually found that they dip eastward, *i.e.*, towards the interior of the mountains, agreeing generally in this respect with the other elements of the complex. The metamorphism is usually most intense in patches of small or moderate size, and the basalt thus indurated offers quite as much resistance to erosion as the gabbro itself, so that it occurs on the ridges rather than in the valleys. Some portions of these highly-altered lavas have a thoroughly coarse texture, and specimens would be unhesitatingly set down as gabbro, did they not still preserve relics of the characteristic amygdaloidal structure. This peculiarity may be taken as indicating that those rocks at least which exhibit it have not suffered bodily fusion in connection with the intrusion of the highly-heated gabbro; but the apparent gradual transitions from metamorphosed basalt to gabbro, though illusory, render the drawing of precise boundaries in some places a task of much difficulty. This difficulty is enhanced by another circumstance. It appears that the basaltic lavas so intimately associated with the large gabbro mass do not in general belong to the same part of the series as those developed on the adjacent moorland country.

* *Summary of Progress* for 1898, p. 137.

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Isle of Skye. (Mr. A. Harker.)

They are much less generally amygdaloidal, and what was there so distinctive a feature ceases to be available as a ready criterion on the more difficult ground. It is probable that in the northern and north-eastern parts of the Cuillins, mapped in former seasons, some rocks have been set down as intrusive diabases and fine-grained gabbros, which would be more correctly regarded as metamorphosed basaltic lavas.

Some of the central and highest mountains (such as those unnamed on the Ordnance map, but known to climbers as Sgùrr Alasdair, Sgùrr Tearlach, and Sgùrr Mhic Coinnich) consist in their upper parts almost wholly of basalt, with subordinate volcanic breccias, penetrated only by a few tongues of gabbro from below. From the extent and thickness of these lavas, they seem probably to be outliers of the rocks above the upper surface of the great gabbro laccolite, which, on this supposition, has a maximum thickness of about 3,000 feet or more.

The gabbro itself undoubtedly consists of numerous distinct intrusions in the form of wedges, sheets, and tongues, but their petrographical differences are not such as enable us to map them separately, even if the scale of the map permitted their delineation. An exception in this respect is the peculiar orange-crusted rock mentioned in the last report as remarkable for its extreme toughness, and for its containing innumerable xenoliths of a more normal gabbro. This rock occupies a considerable area in the western Cuillins, forming the peak at the junction of the Sgùrr Dubh ridge with the main range, and extending along the valley named An Garbhchoire. Here it is penetrated and enveloped by the normal coarse gabbro to the N.E., which is clearly of later date. On the other hand, the orange-crusted rock occurs at two places on the border of the gabbro area, viz., at An Sgùman and on the southern slope of Garsbheinn, and in both places is clearly posterior to the normal gabbro in contact with it. If the several masses of this peculiar rock are to be assigned to one epoch, we may draw the inference, on other grounds a likely one, that the normal gabbro on the border of the tract consolidated at a somewhat earlier time than that in the interior. Petrographical examination shows that the tough orange-weathering rock is of ultrabasic composition. It is usually a picrite, but passes into a pure olivine rock (dunite), and has also bands of troctolite associated with it.

Basic Dykes, Sills, and Sheets.—The intrusive rocks of the western part of the Cuillins and of the basalt country farther west are exclusively of basic (including sub-basic) composition. Acid dykes occur, as already recorded in the eastern part of the Cuillins, and occasionally on the moorlands to the north, but they do not extend westwards, a fact which tends to connect them genetically with the granite of the Red Hills to the east. It may be remarked too that granite veins in the gabbro, as well as independent acid intrusions, are wholly wanting in the western mountains; and even veins of pale felspathic gabbro, aplitic or pegmatoid, traversing the normal gabbro are comparatively rare except in a few places, such as the summit ridge of

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Isle of Skye. (Mr. A. Harker.)

of Sgùrr Dearg. The most westerly independent intrusions of acid rock occur on the north-west slope of Sgùrr Thuilm, and consist of a biotite-bearing felsite—a type not elsewhere encountered.

As before, *basic dykes* were met with in great numbers on the ground mapped during the season. They are least numerous on the higher parts of the plateaux, formed by groups of thick sills. This may be due in part to the fact that some of the dykes supplied the material for individual sills and terminated at them; but the general explanation must be that the sills often presented an impenetrable barrier to dykes of later date than themselves. In many parts of the Cuillins the dykes are quite as numerous as on any portion of the basalt-ground. There are, however, in places considerable tracts of uniform coarse gabbro remarkable rather for the paucity of minor intrusions. Apparently some members of the complex body of gabbro have offered effective resistance to the passage of the dykes,

Comparing the dykes of the mountain district and the belt immediately surrounding it with those of the more distant parts of the basalt-country, and of Skye in general, we find a difference in their direction which seems to be of significance. In the basalt area the great majority of the dykes do not usually depart much from a direction north-north-west—south-south-east. In the mountains and the adjacent belt of country many of the dykes conform to the same law, but the general bearing has been governed by other factors, the principal group of dykes having a roughly radial disposition. They do not point accurately to a single central point, but the dominant set are so directed that, if produced, they would pass near the centre of the gabbro tract, or perhaps through one or other of several points situated within a central area. Further, the strong tendency of a dyke to run on in a straight line often causes it to be prolonged into a part of the tract where it makes an acute angle with the general direction in that place. In addition to the dominant radial set of dykes, there is a conjugate set approximately at right angles to them, the departure from rectangularity sometimes observed being due apparently to the same tendency to prolongation in straight lines. The conjugate set is usually subordinate to the radial, though locally it may attain almost equal importance. A noticeable hade is more frequent here than in the former set, especially in the outer belt of the tract, the inclination being very generally outward from the centre. In those parts of the mountains where the phenomena are most regular and most clearly displayed, we can distinguish by their bearing three sets of dykes: (i.) The radial; (ii.) the conjugate; and (iii.) the north-north-west set. The first two must be considered peculiar to the mountain district, while the third set is part of a much larger system, affecting an area which extends far beyond the limits of the Isle of Skye. It does not seem to be possible to distinguish the dykes of the several sets on petrographical grounds. One peculiar type, however, may be mentioned, consisting of an exceedingly hard and tough rock

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with an orange-yellow or rusty surface. Such dykes are frequent on some of the western mountains, especially in the neighbourhood of the orange-crusted picrite already referred to, with which they are sometimes in visible continuity. They have the same profusion of xenoliths remarked in that rock. Isle of Skye. (Mr. A. Harker.)

The *basic sills* intruded among the lavas make up collectively a considerable proportion of the total thickness. They vary somewhat in petrographical characters. The thicker ones are usually of a medium-grained diabase; others are of finer texture, often with something of a fissile structure. A few are amygdaloidal, but with characters quite distinct from those of the lavas, the vesicles being larger and more sporadic, and often empty. Fragments of the basalt lavas are sometimes enclosed.

The sills are always found to die out in the direction of the mountains, rarely approaching within 500 yards, and often not within 1,000 yards of the main gabbro boundary. Then follows a zone within which dykes are the only minor intrusions. Nearer to the mountains the *inclined sheets of basic rock* which form so prominent a feature of the Cuillins begin to make their appearance, traversing alike the gabbro and the enclosed patches of the volcanic group associated with it. These sheets may occur quite at the edge of the gabbro, or even in the metamorphosed basalts bordering it, but in most parts of the western Cuillins they do not become numerous at less than three-quarters of a mile or a mile from the outer boundary of the gabbro, or at altitudes of less than about 1,500 feet. They are thus quite distinct from the sills which follow the bedding-planes of the basaltic lavas. They are intimately linked with the gabbro, not only by their distribution, but by their inclination, which is always inwards towards the centre of the gabbro area. A greater variety of petrographical types among the inclined sheets also serves to separate them genetically from the sills. Which of these two groups of intrusions is the earlier is a question not easily solved. Both are evidently later than the large plutonic masses of gabbro and granite. Both are sometimes seen to cut through dykes, but this is far more frequent with the inclined sheets than with the sills. This observation, however, is not very conclusive, since we have reason to believe that the dykes in the gabbro area are in great part distinct from those of the moorland country.

Inverness-shire and Argyllshire.

In the progress of the mapping through the west of Scotland innumerable basalt-dykes are met with, having a general north-westerly trend, and presumably belonging to the third group in Mr. Harker's classification. During the past season many examples of this series of intrusions have been noted and marked on the maps. The following illustrations of their occurrence will suffice:—

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Glenelg District. (Mr. Clough.)

Reference has already been made to two series of dykes observed by Mr. Clough in the district between Glenelg and Loch Hourn. Those of the one group have been mentioned in connection with the crystalline schists. Those of the second group are no doubt of much later age, and, as they have a general north-west or north-north-west direction, and are of the same character as those of Skye, already alluded to, they may with some confidence be considered to belong to the Tertiary igneous protrusions of the west coast. They include basalts and dolerites and also some trachytic varieties. The latter are seen in several sections to be later than others of dolerite, and, as has been recorded in other districts, they show, near their sides, parallel rows of spherulites and greatly elongated amygdules.

Southern end of Great Glen. (Mr. Grant Wilson.)

In the district at the southern end of the Great Glen, surveyed last year by Mr. Grant Wilson (*ante*, p. 39) both the granulitic flagstones and the Glen Loy diorite are traversed by numerous basalt-dykes of presumably Tertiary age. These vary in breadth from one to twenty feet, and have a general easterly and westerly trend. They are more numerous on the south than on the north side of Glen Loy. It is possible that they may be connected with the volcanic "necks" on the dividing ridge to the south of the glen.*

Dalmally District. (Mr. Kynaston.)

A few additional examples of this late series of dykes have been noticed by Mr. Kynaston in the course of his work among the older rocks in the region already referred to (p. 42). Several dykes of dolerite, having an east and west direction, were mapped by him in the Ben Laoigh area, and between the lower portions of Glen Lochy and Glen Orchy. A dolerite near the head of Glen Shira also apparently belongs to the same series. It is a typical dolerite of medium grain, with a very fresh appearance under the microscope [8626].

Oban and Kilmelfort. (Mr. Symes.)

In the Oban district numerous dykes, evidently belonging to the Tertiary series, have long been known. During his field-work last season, Mr. Symes came upon a number of additional instances around Loch Melfort. The rocks along the southern shore of that inlet are cut by a series of these basalt dykes, which are numerous and well exposed. They include examples of compound dykes, like that of which an account has already been published (*Summary of Progress* for 1898, p. 155). Two of these may be seen where a stream enters the sea at Kames Bay on the east shore. A couple of olivine-basalt dykes are there split up longitudinally by basalt dykes of a less basic nature, the edges of the latter being chilled against the earlier rock, and showing a margin of black basalt-glass. Another similar illustration occurs at Kilmelfort pier, on the north side of the loch. Close to Kilmelfort and east of the Manse, the basaltic dykes are especially numerous. They stand out there in great vertical walls, rising among the schists, granite, limestone, epidiorite, &c., and as a rule running in a north-west and south-east direction. At a distance of about five miles from Kilmelfort, on Carn

* As described in the *Summary of Progress* for 1898, p. 152

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Duchara, the dykes tend to assume an east and west direction, and vary in composition from a fine-grained compact basalt to a highly crystalline olivine-dolerite. Although they run in numerous parallel lines, no compound examples have been noted among them. West of Loch Losgain Beg, the Tertiary dykes are seen to cut through the felsite dykes at right angles to the lines of flow.

Isle of Jura (Mr. Wilkinson.)

Nowhere on the West Coast do the late basic dykes offer a better contrast to the rocks which they traverse than they do on the western shores of the Island of Jura where the dark ribs of basalt rise through white or pale-grey quartzite. During the past season MR. WILKINSON has mapped a number of them in the portion of the island lying north of Loch Tarbert, where, however, he has found them not quite so numerous as they are further south. They are common on the northern shores of that sea-loch, and are more especially conspicuous at the western headland of Ruantallain, where at least eight dykes rise through the quartzite close to each other. At one part of the coast a dark sill has been thrust between the beds of the quartzite, which dips towards the east, and some of the dykes rise vertically through this sill.

Isle of Arran.

(Mr. W. Gunn.)

The survey of the remarkable succession of igneous rocks in the Island of Arran has now been nearly completed by MR. GUNN. During last season he was engaged in tracing dykes of basalt, pitchstone, and felstone in the central granite area among the crags of the highest hills, a task of some difficulty, as many of the dykes occur in almost inaccessible places, and form deep clefts that are not easy to traverse. The more minutely the granite is examined about the heads of Glen Rosie and Glen Sannox the more numerous do these dykes appear to be. MR. GUNN indeed has been led to believe that they are on the whole quite as numerous in the granite as in any other rocks of the Island. Basalt is the commonest rock among them, but dykes of pitchstone and of quartz-felsite are also abundant. With the exception of those of quartz-felsite, most of the dykes are comparatively small, many being less than ten feet in width. Composite dykes are far from uncommon. They generally consist of felstone with edges of basalt. An interesting example on Cir Mhor has been described by PROFESSOR JUDD.

In the area surveyed from Shedog, including the hill called Ard Bheinn, the rocks form part of the oval complex mentioned in a previous Report as occurring south of the String road between Brodick and Shiskine.* The geology of Ard Bheinn is about the most complicated in the island, but as none of the rocks recently collected there have been sliced for microscopical

* *Ann. Rep. Geol. Survey* for 1896, p. 75. As these pages are passing through the press a great volcanic vent in that district has been discovered by Mr. Peach and Mr. Gunn. (*Ante*, p. 133.)

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(Mr. W. Gunn.)

examination only a general description of the ground can at present be given. Indeed, only an exceedingly detailed description could give any idea of the extreme complexity of the area. The acid rocks embrace granite, granophyre, quartz-diorite, coarse quartz-porphyry, and fine-grained quartz-felsite. There are also basic rocks of several kinds that appear generally to be of older date than the acid rocks, besides later dykes. The number of separate intrusions of these rocks is very great. The rock into which they are intruded is the Lower Old Red Sandstone, which is generally here a conglomerate, but so highly altered as to have quite lost its ordinary character. Some of the basic rocks are highly magnetic, and at one place 550 yards east-south-east from Dereneneach the rock is a natural magnet, and possesses polarity. The characters, relations and age of these rocks remain to be determined.

PLEISTOCENE, INCLUDING GLACIAL.

Though no new facts of importance in the investigation of the Pleistocene deposits of the British Isles have been elicited during the past year by the field-work of the Geological Survey, much additional information has been collected regarding the distribution and local character of these deposits. In the following brief summary of the observations a geographical order will be followed, beginning with the English Midland and Southern Counties, then passing to South Wales, taking the districts of Scotland in order from north to south, and concluding with those of the south-east of Ireland.

Midlands.

Leicester and Rutland. (Mr. Fox Strangways.)

In the portions of the counties of Leicester and Rutland examined by MR. FOX STRANGWAYS he has found the distribution of the boulder-clay and gravel to be somewhat irregular. As a rule, these materials cap most of the higher ground, while the valleys are free from them. There are, however, exceptions to this rule, as over the high ground about Burrow and Somerby these deposits have been almost entirely removed, and also along the ridge from Whatborough Hill to the south-east. A large area free of Drift extends from between Tugby and Goadby eastwards to the north of Hallaton and Horninghold. Besides these tracts nearly all the valleys are devoid of drift in their lower part, except in two instances near Skeffington Vale and near Illston Grange, where boulder-clay is seen in the stream sections. The boulder-clay attains its greatest thickness along the southern edge of the map, a well west of Hallaton being said to be 150 feet deep, and apparently entirely in this deposit. Such a depth, however, must be exceptional, as elsewhere the drift does not appear to be of great thickness. The chief deposits of gravel are at Tilton, Skeffington, Rolleston, Tugby, and Belton. The

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revised edition of the map will show considerable changes in the mapping of the superficial deposits.

Reference was made in last *Summary of Progress* to some interesting particulars regarding the distribution of the boulder clays and boulders in the North Staffordshire region, which were gathered during the revision by MR. LAMPLUGH. In the work of last season, MR. BARROW obtained some fresh corroborative evidence of the same facts in the Leek and Cheadle district. He appears to have traced a portion of one of the marginal lobes of the ice-sheet that moved out of the Irish Sea, and carried with it the boulders from the Lake District. It will be remembered that MR. LAMPLUGH noticed that the ground between Cheadle and Uttoxeter was marked by an absence of these boulders, and he conjectured that the lower layers of the north-western ice, in which these stones were chiefly lodged, were arrested by the steep Bunter escarpment south of Cheadle. MR. BARROW, in confirming this surmise, has found that the arrest took place rather further to the north, but was effected by another prominent topographical feature of a similar kind. He has traced the north-western drift, with its abundant blocks from the Lake country, in great force over the ground to the north of Leek. This drift contains a great number of chips of flint, a characteristic feature of the boulder-clays of the Irish Sea basin. The blocks of igneous rocks from the Lake District cease to be visible a little south of Wetley Rocks. Roughly speaking, a line may be drawn in an easterly direction from this point, south of which these boulders have not been met with. Starting again from the same locality the further limit is no longer an east-west line, but a north-south one. In other words the limit of the drift is marked by a line that forms a right angle at a point a little south of Wetley. The position of this line is shown on a geological map to correspond through a considerable part of its course with the foot of the escarpment of the third grit—the rock that makes the most pronounced topographical feature in the whole area, and would obviously present the most persistent obstacle to the advance of the ice. The area beyond this line often contains no drift except a few Bunter pebbles, which are as ubiquitous in this part of England as chalk-flints are in other areas. On the east side of the Churnet there is no appreciable cover of drift. But the materials used in the construction of walls bear record of the transport of local boulders by ice, for these consist largely of the First and Third Grits, the outcrop of which is often not more than a mile distant. The bottoms of the small but deep valleys in the shales are often full of boulders of these local rocks. It was obviously economical to clear the fields of these blocks and use them for building walls, but it did not pay to undertake the great labour of hauling them out of the beds of the streams, and there they remain to attest the great number of boulders that have been transported by ice, though no drift now remains that can be represented on a map.

North Staffordshire. (Mr. Barrow.

In the western part of North Staffordshire, which has been revised by MR. C. B. WEDD, little can be added to what was said

(Mr. C. B. Wedd.

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(Mr. C. B. Wedd.) of the Drift in last year's *Summary of Progress*. In the Audley and Talke district the drift terminates against the anticlinal ridges of the Coal-measure sandstones on the east, but where these ridges are broken by transverse valleys the drift passes southwards and south-eastwards up these valleys. On a belt of ground about a mile and a half broad, immediately west of these ridges, the drift is thin, except in valleys, while ridges of Triassic and Upper Coal-measure strata often rise from the midst of it. Beyond this it thickens to the west. It consists here as elsewhere of clays, sands, and gravels. The occurrence of shell-fragments in these deposits, which was referred to in last *Summary of Progress*, has been further proved by MR. WEDD during the past year. He has now found these fragments at 46 localities in the district, but few, if any, forms have been noted in addition to those given in the list published in that *Summary*. In the neighbourhood of Caverswall and Blythe Bridge little drift occurs, except in and north of the Blythe Valley, but no shell-fragments have been found in it. Many large boulders of some five or six types occur on the high Bunter ground of this part of the district. In the more westerly ground several peat-mosses occur, resting in hollows in sand, or closely associated with it.

(Mr. W. Gibson.) In the centre of the Pottery Coal-field, MR. GIBSON has observed that the drift deposits are thin and sparsely distributed, though they are developed in considerable quantities in the Trent Valley round Bucknall. At Kidsgrove another example of the edge of an ice lobe may be seen. The highly-inclined Coal-measures there rise abruptly above the Plain of Cheshire, and the drift deposits end off abruptly against the Carboniferous strata at an elevation of 500 feet, but drift sand and gravel occur at Trubshaw at an elevation of 700 feet.

Cheshire. (Mr. T. I. Pocock.) In the district of Crewe and further to the north-east in the country around Macclesfield the Drifts have been mapped by MR. T. I. POCOCK. It is well known that on the west side of the Pennine chain these deposits reach a height of 1,300 feet above the sea. Some patches of this high-level drift have been recently examined by MR. POCOCK. They consist of false-bedded sands with courses of pebbles (derived for the most part from the Lake District and Scotland), and rest here and there on boulder-clay. The amount of boulder-clay at the high levels is, however, small. The best known of these patches (that which yielded the marine fossils discovered by PROFESSOR PRESTWICH), runs for nearly a mile at the foot of an escarpment of grit north-east of Walker Barn. Others have been seen by the brook side east of Forest Chapel. The tops of the ridges above are plentifully strewn with boulders from the Lake country and Scotland, which afford conclusive evidence that some portion of the ice-sheet covered the spur of the Pennine Hills east of Macclesfield. The occurrence of drift and boulders by the brook which flows through Wild Boar Clough shows that the ice passed between Shutlingslow and the main ridge of the Pennine Hills. The peak of the Shutlingslow (two miles south from Forest Chapel), may have been a "nunatak" in the stream

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of ice. No erratics appear to have been recorded from the top of the main ridge, and probably the long escarpment formed by the third grit, which rises to a height of more than 1,800 feet at Shining Tor, barred the progress of the ice to the east. Cheshire. (Mr. T. I. Pocock.)

Besides the isolated patches of drift at high levels a series of mounds of sand and gravel was met with in the Langley Valley, two miles south-east of Macclesfield, about 700 feet above the sea. They are composed of the same materials as the drift at higher levels and take the form of conical heaps or undulating ridges, more or less parallel with the trend of the valleys. Their form, and mode of occurrence, at the point where the valley opens out on to the lowlands of Cheshire, recall the kames of the South of Scotland. They appear to have suffered little denudation since they were deposited. They may have been formed by torrential waters at a time when the ice-sheet barred the mouth of the valley, and the pressure from the north was not strong enough to force it over the tops of the hills.

In the Hilderstone district drift occurs sparingly on the tops of the hills, which rise to 700 feet above the sea, and also in the bottoms of the valleys, but the slopes are generally free from it. Ice-worn surfaces were met with near Fulford which indicate that the ice passed down Fulford Dale in an east-south-east direction. The drift, which is of the type described by Mr. Lamplugh,* is mainly composed of *débris* of Bunter pebble-beds with a mixture of red clay where its rests on the Keuper Marl. The occasional presence of striated pebbles from the Lake country clearly indicates its glacial origin.

In the Crewe district the drift is of the type common all over the Cheshire Plain. It is not more than 40 feet thick near Crewe, but is much thicker elsewhere. The false-bedded sands, which occupy a larger area than the clay in this district, can be traced continuously from Crewe Park through Weston and Wybunbury to Willaston. Here and there in brook-sections they may be seen to occupy a position between an upper and a lower boulder-clay. But as a rule this is not the case.

The three-fold succession described by Mr. De Rance in his Memoir on the Drift of South-west Lancashire, where the upper clay rests on an irregular surface of middle sands, or of a lower clay which closely resembles the upper, may hold good in the Crewe district. But the difficulty of distinguishing the two clays makes it impracticable to establish such a relation, or at least to use it for purposes of mapping.

Of the erratic boulders found in the course of Mr. Pocock's work last season the great majority belong to the same rocks as those described by Mr. Harker in the *Summary of Progress* for 1898. Some of the others were submitted to Mr. Peach, and were considered by him to belong to the Silurian grauwackes and granites of the south of Scotland. Another may have been derived from the Calciferous Sandstones of the Border-country.

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* *Summary of Progress* for 1898, p. 160.

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Hampshire Basin.

(Mr. Clement Reid.) The Drifts mapped by MR. CLEMENT REID in the Avon Valley consist in the main of tier above tier of gravel terraces, the highest of which rises fully 300 feet above the Avon, and not improbably dates back to Newer Pliocene times. These higher gravels are mainly preserved on the east side of the river, and, as is the case in all the Hampshire Basin, the gravels nearly cease where the Chalk crops out. The reason why the ancient valley gravels are so commonly confined to the Eocene area, and scarcely cross over to the Chalk, is by no means obvious, though it is probably due to the peculiar type of denudation which took place under an Arctic climate, when the undulating surface of the Down was frozen and no longer pervious. The 100 foot terrace (about 100 feet above the Avon) is the lowest of the gravel terraces here referred to. It is a continuation of the Bournemouth sheet, and contains, like that sheet, Palæolithic implements.

The Valley Gravels can sometimes be divided into two or three terraces, as MR. WESTLAKE has already shown; more commonly they form a continuous slope, rising 40 or 50 feet above the river, where the terrace abuts against the steep bluff which everywhere borders the Avon flat. These gravels yield remains of Mammoth, and also rare Palæolithic implements; but, like the older series, they are usually decalcified, and show no trace of fossils.

In the adjoining Dorset area, mapped by MR. DIXON, a few outliers of the high terraces are to be found; but the highest is only 240 feet above the river, and is probably somewhat newer than the sheet over which the Downton and Southampton road passes.

Sussex.

(Mr. Lamplugh.) In the area of Sussex, which has already been referred to (p. 135) as having been mapped last season by MR. LAMPLUGH, the oldest superficial deposit is a coarse, flinty rubble, which forms an irregular capping on plateaux of limited extent on the Folkestone and occasionally on the Sandgate Beds south of the Rother valley. These little plateaux, much dissected by erosion, slope gently northward (*i.e.*, away from the South Downs), but end off boldly above the depression occupied by the Gault in steep bluffs simulating an escarpment, sometimes 50 to 80 feet high. The rubble on these plateaux has an extreme depth of nine or ten feet in "piped" hollows, but is oftener a mere ragged film, through which the underlying formation continually breaks. It is best developed on the commons of Heyshot, Ambersham, Graffham and Coates, and is much dug for road-mending. This material was a subject of discussion nearly fifty years ago

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by Sir R. I. Murchison,* and more recently by Mr. J. V. Elsden.† Its accumulation probably dates back to the Glacial Period, and must have taken place under peculiar physical conditions. That the plateaux have suffered very little surface-erosion since prehistoric times is shown by the position of the tumuli on some of the spurs overlooking the Gault depression.

South Wales.

(Mr. Strahan Mr. Tiddeman, and Mr. Cantrill.)

The following summary of work of Messrs. Strahan, Tiddeman and Cantrill last season among the Pleistocene phenomena of South Wales has been drawn up by Mr. Strahan. In previous Reports reference has been made to the Brecknock escarpment of Old Red Sandstone as having been no less important as an ice-parting in Glacial times than it is as a water-parting at the present day, but in the *Summary of Progress* for 1898 several facts were cited which suggest that the western end of that escarpment was crossed by the ice by way of the Crai and Tawyneu valleys. Further evidence of such crossing has been obtained by Mr. Cantrill in Cwm Garw. He finds that in that valley the ice, as shown by striæ on rock in place, moved in a general southerly direction, and that the valley contains many boulders of Old Red Sandstone, although the outcrop of that rock occurs beyond the head of the valley and on the other (northern) side of the water-parting. He infers that the ice overflowed the range southward by the pass of Pen rhiw wen, at a height of 1,618 feet, and that this overflow must have been due to the Vale of Towy having been filled with ice to at least that height.

Mr. Cantrill notes also the occurrence of many striæ, *roches moutonnées*, and bevelled crags on the Millstone Grit west of the Gwys. Tyle Garw shows numerous glaciated surfaces, the striæ indicating an ice-flow down Cwm Twrch in a south-south-west direction. The high Millstone Grit plateau lying between the rivers Tarch and Llynfell is glaciated right across its summit (1,656 ft.) in a direction towards south 15° west, by ice which must have moved up from somewhat lower ground to the north.

Along the north-west flank of the ridge known as Tair carn isaf, striæ have been recognised up to a height of 1,371 feet, with a direction ranging from south 60° west to south 15° west, indicating a general south-west flow parallel to the Llwchwr Valley.

The undulating plain underlain by the lower part of the Coal-measures is thickly overspread by a tough blue till full of large and small glaciated boulders, chiefly of Millstone Grit, but with abundant pieces of Old Red Sandstone and Carboniferous Limestone also. Through this deposit the rivers Giedd, Gwys, Twrch, and Llynfell have cut steep-sided ravines down into the under-

* *Quart. Journ. Geol. Soc.*, vol. vii., pp. 351-361.
† *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 637-656.

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(Mr. Strahan, Mr. Tiddeman, and Mr. Cantrill.)

lying rocks. These post-glacial ravines run about south 10°-15° west, and cut obliquely across the gentle ridges into which the Drift was piled, which run west 10° to 30° south. The direction assumed by these ridges prepares us for the fact that the main mass of the Brecknock Drift travelled along the north crop westwards, though some also certainly found a way down the Upper Clydach and Egel valleys past Rhyd-y-fro.

The Tawe Valley, like that of the Neath, formed one of the main outlets for the Brecknock Drift. Boulders of Old Red Sandstone and Limestone abound along its whole course, and are even piled up high on the hillsides around Swansea Bay. Striæ have been noticed in a paving quarry on Allt-wen, 400 feet above the bottom of the valley at Pontardawe, and at about the same elevation on the top of a sandstone-crag west of Ynys-meudwy. On Kilvey Hill, east of Swansea, there are many glaciated rock-surfaces, but none on which striæ were sufficiently preserved to be recorded. The Brecknock Drift runs up to a height of 550 feet at least on this hill; it is doubtful, in fact, whether there is any ground around Swansea which was not overflowed by the ice. The Drift in the upper part of the Tawe Valley may be described as a till, but in accordance with the usual rule it gets more gravelly farther from its source. The boulders, which are chiefly angular near the source in Brecknock, get steadily rounder, until at Swansea they are all true pebbles. The whole deposit also changes its character and assumes a rough stratification, in which sands alternate with pebble-gravels, while at the same time it has been heaped up into the ridge-and-hollow form so characteristic of glacial gravels. This form is admirably illustrated from Glais downwards. At that place a great dam of coarse gravel, reaching to a height of about 100 feet above the alluvium, extends far out in the valley, deflecting the river and leaving a narrow outlet for it at Clydach. Llansamlet also is situated among mounds of sand and gravel, the hollows between which have been filled up by flood-deposits of the Tawe and partly by peat.

The Drift-dam at Glais reproduces the phenomena already referred to* with respect to the Vale of Neath. The sands and gravels seem to have been the work of effluents from the ice-foot, and their development, especially in the form of a conspicuous ridge such as that at Glais, points to the ice-foot having lingered at that spot. It may be remarked of that ridge also that it presents a fairly gentle slope towards the north, but an extremely steep face to the south. It therefore has exactly the form which has been noticed in ice-foot accumulations at the present day, the gentle slope being produced by the advance and retreat of the ice over the rubbish, and the steep face by the extrusion of the material from the ice-foot.

The examination of the superficial deposits of Gower by Mr. Tiddeman has enabled him to prove a fact of much importance with respect to the relative age of the Raised Beach and the

* *Summary of Progress* for 1898, p. 165.

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Glacial Deposits of the neighbourhood. This relation had been discussed, especially by Falconer* and Prestwich, but in consequence of the researches having been carried on chiefly in connection with the exploration of caves, and in a part of the coast where the evidence was obscure, Prestwich found himself unable to form a decided opinion. From an examination of the coast between Bacon Hole and Mumbles Head, MR. TIDDEMAN has satisfied himself:— (Mr. Strahan, Mr. Tiddeman, and Mr. Cantrill.)

1. That the Raised Beach is pre- or inter-glacial.
2. That the bone-beds which rest upon it in the caves are continuous with a layer of angular débris ("head") which lies upon it.
3. That the Glacial Beds lie upon this.
4. That these in turn are often covered with a deposit of angular débris of post-glacial age.

The lowest bed seen so far consists of a mass of pebbles, more or less crowded with shells of such species as are living on the coast at the present day. The pebbles consist of limestone, with an occasional specimen of Old Red or Carboniferous sandstone. There are also a few fragments of yellow flint or chert of doubtful origin. The conglomerate is firmly cemented. This deposit is overlain by a foxy-red sand, which, though impersistent, often runs for some distance. It is evidently a sand blown up from the foreshore and sometimes contains land-shells (*Helix*), which abound on the modern blown sands. The presence of this bed implies a sandy foreshore in some parts where no sands are found at low water now.

The next deposit rests on the sand, or, in its absence, on the beach or on the solid rock. It is to all appearance made up entirely of broken and angular limestone from the crags above. Its thickness varies greatly according to local circumstances. The glacial drift which rests upon the last-described band offers a remarkable contrast. It contains but little limestone, while Carboniferous sandstones and pebbles of Old Red Sandstone abound. This drift, which sometimes reaches a thickness of 40 feet, is in some places made up of rounded boulders and gravel, while in others semi-angular débris is more common.

Ross-shire and Inverness-shire.

During the past working season fresh proofs have been collected by MR. PEACH in the eastern parts of Ross-shire of the magnitude of the later glaciation of that region, to which allusion has alreadybeen made.† Both from the direction of the striæ on the bare rock-surfaces, and from the distribution of the boulders, especially those of the conspicuous Inchbae Dingwall District. (Mr. B. N. Peach.)

* *Pal. Memoirs*, vol. ii., pp. 357, 358, 535.
† *Summary of Progress* for 1898, pp. 174, 175.

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augen-gneiss, it is manifest that the ice was developed on such an enormous scale that the eastern margin of the great confluent glacier of the Blackwater and Conan rose high up the flanks of Ben Wyvis, and that on its emergence upon the low ground to the south of that mountain the ice must have fanned out towards the east. The southern slopes of the hill are terraced with successive lateral moraines strewn with boulders of the Inchbae rock, which mark successive stages in the decrease of the glacier.

Beauly District. (Mr. L. Hinxman.)

The glaciation of the region lying to the south of MR. PEACH'S ground has been studied by MR. HINXMAN, who has observed that in the district between Strath Conan and Strath Glass most of the glacial phenomena are again found to belong to the later phases of the Glacial Period, few traces having been detected of the earliest glaciation since these have been in large measure effaced by the gigantic glaciers of later time.

On the summit ridge of Bheinn a' Bh'ach Ard, in the Struy forest, large erratic blocks of muscovite-biotite-gneiss and granite are forced up to heights of 2,800 feet. These must have been deposited by an ice-sheet coming from the west and over-riding the general surface of the country. Hard grey till, filled with angular blocks, underlies the later moraine deposits in the upper part of Glen Orrin near Aradie; and isolated patches of a similar early boulder-clay are found on the slopes of the higher hills north of Struy. On the ridge between Scatwell and Glen Orrin a few striæ pointing south-south-east have been observed. These indicate an ice-movement across the main valley system, and may possibly be due to the early ice-sheet. They may, on the other hand, have been produced by a branch of the Strath Bran glacier coming from the north through the narrow glen at the foot of Loch Luichart.

The lower hilly ground to the east of Erchless is for the most part bare of drift, and the rocks are well glaciated. The numerous striæ point north-east to east-north-east, a direction slightly oblique to the trend of the valley. The glaciation of this area and of that adjoining it on the north may be assigned to an early period of the valley glaciation—the period of the confluence of the Conan, Orrin, and Strathfarrar glaciers on the comparatively low ground to the east of Erchless and Corriechallie.

It is the last phase of the valley ice—that of small individual glaciers shrinking up the glens—that has produced the most striking glacial phenomena in the district. In the lower parts of Glen Orrin and Glen Goibhre the terraced lateral moraines, produced by the shrinking ice, are well displayed; and a particularly fine example encircles Cnoc Judais, the steep hill of conglomerate that rises west of the farm of Auchmore. East of this point they merge into the lateral moraines formed along the southern edge of the Strathconan glacier on the hill slopes above Balavulich and Ord Mains, and descending to the lower ground about Ord, pass into a series of flat-topped mounds and ridges of fluvio-glacial gravel, the latter finally spreading out into a fan and merging into the deposits of the 100 feet beach between High-

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field and Muir of Ord. Higher up Strathconan, the terminal moraines of the retreating glacier cover the bottom of the valley about Scatwell, and immediately west of Muirton Mains can be seen surrounded by, and no doubt resting upon, the 100-feet beach. Beauly District. (Mr. L. Hinxman.)

Large boulders of the Inchbae augen-gneiss, together with blocks of gneiss, schist, and amphibolite, are found in great numbers about Arcan on the smooth drift-covered ridge between the Conan and the Orrin. The latter river seems to form the southern boundary of the dispersion of these augen-gneiss erratics. Eastwards, blocks of the same rock are numerous on the southern slope of the Black Isle, as mentioned in last *Summary of Progress* (p. 174). The stone circle at Carnurnan is formed of blocks of this gneiss, together with a few of mica-trap which enclose pebbles out of the Old Red Conglomerate. Mr. Peach has described a rock of this nature as occurring on Creag a Chaoruinn, south of Loch Garve, 12 miles to the west-north-west, from which place these erratics have not improbably been derived.

Among the glacial deposits of Scotland must be reckoned the older strand-lines or raised beaches which form so marked a feature on the eastern and western coastlines of the country. Some of these terraces are admirably developed among the northern firths from Inverness to the borders of Sutherland. One of the most marked of them, known as the 100-feet terrace, has been traced by Mr. Hinxman up the valley of the Conon to the extreme limit of the 100 feet contour opposite Torrachilty. Between Marybank and Clachuile Inn it is much denuded and sometimes obscured by river gravel. Immediately west of Muirton Mains it forms a considerable feature, and nearly surrounds a promontory of morainic material which, as mentioned above, appears to have been laid down upon the pre-existing beach. At this point the beach is composed of finely-laminated blue and grey estuarine clay, in which marine shells, not at the time identified, were obtained during draining operations.

The hollows and hill-slopes in Glen Goibhre and the Erchless Forest, and the plateau between Scatwell and Glen Orrin, are occupied by peat mosses of considerable extent and thickness. Most of the more accessible of these are dug for fuel.

In continuation of his previous work in the district of Fannich Forest Mr. Horne mapped some well-marked groups of valley moraines in the Abhuinn Nid and Cabuie Valley. When later in the year he transferred his station to Strath Nairn he found good evidence of the north-easterly movement of the great mass of ice which emerged from the Great Glen and spread out over the low grounds of the Moray Firth. This evidence consists of rock-striæ, the transport of materials in the boulder-clay and the dispersion of erratic blocks. The phenomena of the later glaciation were observed to be well represented by a fine development of valley moraines. Fannich Forest and Strath Nairn. (Mr. Horne.)

In the west of Inverness-shire Mr. Clough has gathered

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Glenelg District. (Mr. Clough.)

further information regarding the glaciation of the mountainous region to the south of Glenelg. In the area west of Beinn a'Chapuill and Ben Sgriol he has not observed much drift, but many of the glens to the east show extensive tracts of morainic heaps. Near the tops of Ben Sgriol (3,196 feet) and the Saddle (3,317 feet), and some other hills, he has observed flats and slopes which are chiefly covered with angular or subangular slabs of Moine-rocks like those which occur *in situ* near at hand, but without any admixture of stones, which must necessarily have been transported from a great distance. On the south slopes of the Saddle ice-striæ, pointing west and south-west, were noticed at a height of about 2,500 feet. The tops of Beinn a' Chapnill (2,421 feet) and of Sgurr na Laire Brice (2,326 feet) seem to have been covered by the ice, for ice-stræ may be seen close to the top of each; the direction of the striæ on Beinn a' Chapuill is south-east, and on Sgurr na Laire Brice north-east or east-north-east.

The terrace of the 100-feet raised beach is well seen on the south side of Gleann Beag of Glenelg. It runs for nearly a mile and a half above the mouth of the glen, and appears also on the coast near An Gurraban and Rudha Mòr. The hamlets of Arnisdale and Corran are built on a raised beach which, along the sea margin, reaches in places to a height of about forty feet. But the continuation of this beach inland in a terrace-form at the sides of Arnisdale river reaches a considerably greater height. On the north side of the river, about half a mile east-south-east of Arnisdale House, within the area of the high terrace, various banks and mounds are to be seen which resemble moraines. They seem all composed of well-rounded gravel.

On the south side of the same river, opposite to these mounds a terrace-shaped deposit of fine, stoneless, laminated, sandy clay, and sandy gravel lies at a height of perhaps 200 feet above the sea. At least one other terrace-shaped deposit occurs at a greater height, but its materials are not seen in section. Possibly these sediments were laid down at the side of an ice-tongue, which still filled most of the valley.

On the west side of Allt Coire Utha a large landslip has taken place. It appears to have at first dammed the burn back and given rise to a small lake. But the site of the lake is now filled up with gravel brought down by the stream. Other landslips have occurred on the south side of Gleann Beag (near Balyraid), and on Druim Fada.

Argyllshire.

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

The glacial phenomena of Glen Spean and the Great Glen have long been classic in geology. They have never been actually mapped, however, in a detailed survey on such a scale as that now employed in the field-work of the Geological Survey. Mr. Grant Wilson, to whom this region has been assigned, has now made some progress with the mapping of the

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superficial deposits, and has furnished the following notes regarding the results obtained last season. One interesting feature of his mapping is the discovery of evidence for the former existence of a succession of lakes at various levels below the famous "Parallel Roads," during the time of the shrinkage of the ice-barrier that gave rise to them. Glen Spean and the Great Glen. (Mr. Grant Wilson.)

No characteristic of the region stands out more strikingly than the proofs of the enormous magnitude of the ice-streams during the later glaciation, especially on the west side of the Great Glen. At that time the ice while at its greatest extension, must have formed a large confluent glacier or ice-sheet over the ground between Loch Eil and Loch Arkaig. It moved eastward descending into the wide glen, and leaving traces of the successive stages of its decrease in the form of large lateral moraines which still terrace the slopes of the hills, and the sides of the valleys from top to bottom. So vast was this body of ice that it actually crossed to the south-east side of the Great Glen.* Round the township of Brackletter south of the mouth of the river Spean, the direction of the rock-striæ is from east 15° north to east 25° north; also on the east side of Loch Lochy to the south of Glen-tintaig House, the striæ vary in direction from south 5° east to south 25° east. Two miles inland on the south-west shoulder of Srôn nam Bà, a fine series of striæ has been recorded These generally indicate a movement in the direction of east 15° to 35° S, and that the ice from Glen Arkaig had passed over the hollow now occupied by Loch Lochy and the Dochanassie district on its eastern side. From the direction of these different sets of striæ it appears that part of the ice from Loch Eil and the whole of that from Glen Arkaig converged towards the Spean valley.

That the movement of the ice of the later glaciation was from west to east over this district of Lochaber is further indicated by an analysis of the contents of the moraines. On the Fort Augustus Railway, below the Free Church of Kilmonivaig, a cutting has recently been made through sand and gravel resting on packed morainic detritus. As the material was removed the boulders of the moraine were placed on one side. A careful examination showed that fully 95 per cent. of them consisted of various rocks that occur *in situ* towards the west. A similar result has been obtained from an examination of the moraine sections exposed on the roadside that leads from Torlundy to Linachan.

Farther proof of the same general trend of the ice has also been collected in a study of the morainic detritus which fills the bottom of the valley of the Allt a' Mhuilinn, on the north-west slope of Ben Nevis. From the foot of the hill, for some miles to the east of the watershed, the underlying rock is granite, while the moraines are almost entirely made up of rocks from the Loch Eil basin and the country to the west. The ice has here not only carried the morainic detritus across the wide valley from Corpach to Inverlochy, but also up the slopes of

* See Mr. T. F. Jamieson's paper, *Quart. Journ. Geol. Soc.*, vol. xix., p. 235.

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Glen Spean and the Great Glen. (Mr. Grant Wilson.)

Ben Nevis to a height of at least 2,000 feet above sea-level. It is evident that during this period of glaciation the local glaciers that emanated from the Ben Nevis range could only have been insignificant in size. Indeed, at no time could these glaciers have been large, seeing that the *nevé*-field of this range is so limited in extent.

During the past season numerous observations have been made by Mr. Grant Wilson in illustration of the later stages of the ice as it melted back towards the west, and the physical features that it gave rise to in Glen Spean. To the north of Spean Bridge the 855-feet Parallel Road is not correctly laid down on the one-inch Ordnance map. It should end about half a mile further to the east than is there represented. To the south of this point a well-marked terrace at the level of 420 feet extends from behind the house of Tirandrish to the foot of Glen Collarig in Glen Roy. This terrace is composed either of fine sand or of glacial silt, and where the Allt-na-Grudiareach has cut a deep trench across it, the following section is exposed :—

	Ft.	In.
Sandy soil	21	5
Light brown glacial silt, laminated ,with a few stones	2	0
Fine clean gravel, stones up to the size of peas	0	5
Very fine clean sharp sand	1	6
Gravel, sharp and clean	0	6
Sand with gravel bands	0	9
Light brown glacial silt, laminated with stones	1	0
Gravel, sharp, bottom not seen	3	0
	10	8

A similar terrace at the same level has been traced on the south side of the River Spean from a point opposite Tirandrish round by Killiehonnet, thence up the Cour Valley and Allt-an-Loin till it merges into the flat which marks the site of Loch Lianachan. Fringing the south-side of the Allt-an-Loin, this terrace forms an extensive flat to the south of Dalnabie and continues up the valley as far as a point opposite the Roman Catholic Chapel of Glen Spean.

At many points around Dalnabie numerous landslips and cuttings show the terrace to be composed of fine glacial silt or sand, and in some cases these rest upon morainic detritus. Between the Roman Catholic Chapel and the foot of Glen Collarig, a well-marked flat-topped, broad terrace lies around the west foot of Meall Dhoire with its shore margin reaching to a height of about 420 feet. At the roadside below Auchaderry* its slope towards the deep water of the lake is seen to consist of 20 feet of fine white glacial sand in thin horizontal layers.

These three portions of a terrace appear to mark the site of another glacial lake in Glen Spean, which stood at a height of 420 above the present sea-level. When the ice which formed the barrier of the 855-feet lake had sufficiently diminished, its waters would find their way out in the direction of the valley of

* *Op. cit.*, p. 251.

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the Lundy, at the same time depositing the large accumulation of false-bedded sands and gravels which are found at the head of the River Lundy between Torr Sonnachain and Sgor a' Pheanais. The 855-feet lake of Glen Spean and Glen Roy would thus be reduced to the 420-feet lake of Glen Spean, with its ice barrier stretching across the Spean Valley at Tirandrish. The surplus water of this lower lake would escape over the Col 420 feet at the south-west corner of Lake Lianachan. The barrier at Tirandrish must have been entirely composed of ice, for no terminal moraine extends across the valley at this point. (Glen Spean and the Great Glen. (Mr. Grant Wilson.)

The next stage in the retrocession of the ice sheet from the Spean Valley is marked by the lowering of the 420-feet lake and its replacement by that of 300 feet. This later sheet of water was about 5½ miles long with an average breadth of half a mile. It stretched from Brackletter to the foot of Glen Roy. On the north side of the railway viaduct the line passes into a cutting* 250 yards long, which gives the following section of the materials deposited at the bottom of this lake.

	Ft.	In.
Fine gravel - - - - - - - - -	3	0
Fine laminated brown silt with a few stones -	20	0
Fine laminated blue silt (contorted by shore ice) bottom not seen - - - - - - - -	3	5
	26	5

Both the brown and blue silt are arranged in fine horizontal laminæ, and through both are scattered a few glaciated pebbles. At the foot of the sloping bank the silt has been contorted and folded, possibly by the effects of the stranding of ice during the period of deposition. Around the church and the house of Blairour, numerous pit-sections show that the waters of the lake here deposited bands of fine glacial silt and sand with scattered glaciated pebbles. From the road-section below the church the thickness of the lacustrine deposit is seen to be about 50 feet.

On the south side of the river around Dalnabie, the finer deposits left by this lake have been denuded by the River Spean, and are replaced by the coarser and more recent alluvial gravels, but on the north side between Inveroy and Roy Bridge a broad, well-marked terrace with its shore-edge reaching to the 300-feet contour-line has been preserved.

When the lake at a level of 420 feet was superseded by this lower lake, the River Roy at the foot of its glen cut away a portion of the deposit laid down on the floor of the higher sheet of water, and left a long sloping terrace of silt covered by a thin deposit of gravel, now found midway between the two benches which mark the limit of the respective lakes.

A good part of the silt and sand deposited by the muddy waters of this lower lake has since been wholly or partially removed by the stream which has laid down in its place at a

* *Summary of Progress* for 1898, p. 171.

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Glen Spean and the Great Glen. (Mr. Grant Wilson.)

lower level terraces of coarse alluvial gravel. This change is well seen in the railway cutting on the south side of the Spean, which passes through one of the upper river-terraces, showing current-bedded stream-gravel resting unconformably on a denuded surface of horizontally-bedded glacial silt. The barrier which impounded the waters of this lake extended from Brackletter to Torr-an-Eas, and was partly composed of ice and partly of moraine-detritus. At the cross-roads below Torr-an-Eas, the moraine has a height of 361 feet. On the opposite side it is represented by the flat-topped hill of Brackletter (371 feet), and in all probability once stretched right across what is now the deep river-gorge. This large accumulation of morainic detritus has an average breadth of about 500 yards.

In a railway cutting below the Free Church of Kilmonevaig, and on the west side of the barrier, it is seen that the portion which has been removed by the river consists of hard, packed morainic detritus, containing large boulders. The moraine in this cutting reaches a height of 230 feet above sea-level, and on its denuded top there rests a capping of false-bedded sand and gravel, about 15 to 20 feet thick. The dam would thus appear to have been lowered to the top of the moraine, while the outflowing water deposited the sand and gravel. The surplus water of the lake found its way into the Allt Achadh na Dalach, to the south-west of Spean Bridge. The present level of the col is a little over 270 feet, but when the lake overflowed in this direction, there may have been a considerable body of ice resting on the col, for the bottom of the gap is covered with small moraines, and below Auchnabobanne the valley is crossed by three large ridges, composed of morainic detritus. These mounds more nearly resemble kames than ordinary terminal moraines. They rise above the usual moraine hillocks, cross the valley with a serpentine course, and creep up the rising ground on both sides to at least 100 feet higher than in the centre of the valley. They are possibly due to the water, which must have circulated upon, within, or beneath the melting ice-sheet.

After the ice finally retreated from the foot of the Spean gorge, a large glacier would seem to have still issued from Glen Arkaig, and to have pushed its terminal face from Clunes to the braes on the west side of Brackletter. This ice-barrier would raise the surface of Loch Lochy. That the lake did really stand at a higher level is proved by the well-defined terraces, 35 feet above the present level of the water between Mucomir and Glenfintaig House, and around Blar-an-lochain.

Dalmally District. (Mr. Kynaston.)

From Dalmally MR. KYNASTON was able to map the drifts and other glacial phenomena, both southwards across the watershed towards Loch Fyne, and northward in the glens that drain into Loch Awe. From that part of Glen Shira nearest to the Cladich Burn he traced a continuous series of morainic mounds across the intervening divide and down to Loch Awe-side. The ice from the Ben Bhuidhe ground, no doubt, in part at one time travelled in this direction, and spread completely over the hills

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between Glen Shira and Glen Aray. The presence of a large boulder of monzonite, of the Ben Bhuidhe type, at the head of Glen Aray is of interest in this connection. Dalmally District. (Mr. Kynaston.)

In Glen Lochy the morainic-drift is well marked and extensive, and good sections of the mounds of loose material may be seen in the railway cuttings.

In the Glen Orchy area the larger burns (*e.g.*, Allt Corrie Bhiacar) have often cut their channels through more than 40 feet of mixed morainic material. Continuous morainic deposits may be traced from the head of Glen Strae down into Glen Orchy to the east, into the Black Mount on the north, and over into Glenkinglass on the north-west. In this district boulders of rocks, possessing characteristic and easily recognisable features, such as monzonite and the porphyritic augite-diorite, show that their dispersion has mainly followed the lines of the greater glens. Occasional large boulders of the Glen Orchy monzonite occur at Dalmally, while in the more immediate neighbourhood of the parent rock a line of boulders may be followed in a south-westerly direction, up a branch of the burn in which the rock occurs in place, and up the hill slopes between that branch and Glen Orchy, to a height of nearly 1,500 feet, or about 600 feet above the exposed parent rock.

In the district around Kilmelfort MR. SYMES has observed that the striation on the ice-worn rock surface has a general east and west direction, varying up to as much as W. 45° S., which is the trend of striæ a mile to the south-west of the village. The ice is thus shown to have moved westwards, and to have inclined to the south of west, and even to south-west, according to the form of the ground. The most noticeable departure from this general trend was observed in the Pass of Melfort, which runs north and south, and where the striæ follow the same direction. As a rule these ice-markings have usually disappeared from the exposed surfaces of the knolls and crags of andesite, owing to the weathering of these volcanic rocks. But along the sides of the sea-lochs between tide-marks they are often well preserved. They abound on the eminence Carn Duchara, trending towards W. 20°–25° S. Kilmelfort District. (Mr Symes.)

A few additional particulars regarding the glaciation and old sea-margins of the Island of Jura have been gleaned by MR. WILKINSON. Further evidence has been obtained by him of the westward movement of the ice-sheet by which the island was overridden. This consists both of rock-striæ and of the materials of the boulder-clay. Polished and striated surfaces of rock are common at all heights. There are indications of later glaciers in the moraines that have ponded back the drainage at higher elevations, and have thus given rise to numerous small tarns. The more ancient and extensive glacial drift consists of boulder-clay, which is widely distributed, and is banked up against the sides of the higher hills. The matrix of this clay is exceedingly tough, and is often of a red colour, which bleaches white or grey on the surface. It is plentifully charged with well-rounded, sometimes striated, boulders of quartzite, Island of Jura. (Mr. Wilkinson.)

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Island of Jura. (Mr. Wilkinson.)

epidiorite, dolerite, and red porphyry rocks, which are all found in place on the island. But there occur also pieces of red sandstone and andesite, which may have come from the volcanic district of Lorne. The west coast of Jura has long been celebrated for the number and admirable freshness of its raised beaches. To the north and south of Shian Bay they form a striking feature, also at the entrance of Loch Tarbert, and for some little distance along its northern shores. These terraces vary in elevation from the present beach up to the 200 feet contour line, which they do not pass. They consist of well-rolled shingle, which extends in patches for many miles; 90 per cent. of their stones are quartzite, which have been bleached by weathering into a dazzling white. In spite of their low elevation, they thus form a land-mark for a considerable distance at sea. They stretch out either into plateaux of bare shingle or moss-covered flats, behind which the ground rises rather abruptly along their inner margin. They extend inland in some instances for a mile. Occasionally one of the lower terraces has been a storm beach which has ponded back the drainage and now appears as a rampart of shingle with a small lake behind it.

Aberdeenshire.

Deeside. (Mr. Cunningham Craig.)

The survey of the high grounds in the upper part of Deeside has included the mapping of the various glacial deposits of that region by Mr. Cunningham Craig. In the portion of the Cairngorm mountains recently examined, he has found later glaciation to be well-marked, especially in Glen Luibeg, where the moraines are noticeable for their size and regularity of form.

In the Lochnagar district, on the ridge dividing Glen Gelder from Glen Girnock, evidence of an abnormal drainage has been obtained. More than half-way up Glen Gelder, at the lowest parts of the ridge, broad flat cols may be observed. They are triangular in shape, with their apices to the eastward, where they terminate in steep dry gullies, which form the heads of small burns, that traverse the flat hollow of Glen Girnock and flow into the main stream of that valley. These gorges in the granite are not in lines of faults or crushes, and under present conditions could not have been cut by running water, as they do not drain any appreciable area. It seems probable that the explanation of them may be somewhat as follows. The ice-sheet, moving from the north-west, has overridden and completely filled the great open hollow of Glen Gelder, which probably owes its wide and shallow shape in great part to glaciation. During the decline of the cold a great mass of ice may have remained in the hollow, leaving the upper part of the glen comparatively clear, and diverting the drainage over the cols to the eastward and northward, where a similar gully is seen. Possibly a lake, or a number of small lakes, was formed in the

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upper part of the glen, about the sides of the mass of ice as it melted. Drainage to the westward was barred by the high ground of Lochnagar. If such conditions were maintained for a sufficient period, the escaping water, pouring over into Glen Girnock, would have been enabled to cut the gorges referred to. The material brought down in this manner would be spread over the open expanse of Glen Girnock, which may have been in great part free from ice. In confirmation of this suggestion, it may be mentioned that the superficial deposits, which mask the hollow of Glen Girnock are almost entirely composed of granite *débris* near the western ridge. That the northern ice must have swept into Glen Gelder in great volume is proved by the numerous fragments of schistose rocks in the drift of that glen, even in its upper part, where no sedimentary rocks can be detected *in situ*. The irregular and often ill-defined morainic mounds, which are scattered over the glen, consist almost entirely of granite *débris*, and were probably formed on the surface of the ice, and were deposited as the mass melted. Deeside. (Mr. Cunningham Craig.)

Dumbartonshire.

While the revision already noticed (p. 38) was in progress in the district of Loch Lomond an opportunity was afforded to examine with some care the marine deposits which have long been known to exist along the margin of that lake. Attention was first called to these deposits as far back as 1823,* and their enclosed fauna has more recently been studied by Messrs. Crosskey and Robertson.† In his recent revision of the district Mr. Cunningham Craig traced the deposits where they have been preserved at intervals along the western shore and on several of the islands. They usually lie below the 50 feet contour-line, but on Inch Lonaig apparently rise to 100 feet above sea level; they are much denuded and cut into by streams, and are frequently covered by river-alluvium or the present lake-beaches. Their upper part usually consists of sandy gravel, which varies in coarseness locally, and sometimes contains erratic boulders of considerable size. Underneath this coarser material a fine yellowish or grey clay frequently occurs, with a few well-rounded pebbles and marine mollusca, which are sometimes found in the position of the living organism. This clay is frequently found in a somewhat denuded state under more recent deposits, *e.g.*, at Rossarden, where it is covered by one foot of recent lake-beach gravel. (Mr. Cunningham Craig.)

Inch Moan and Inch Cruinn are denuded remnants of a sea-beach which apparently stretched almost across the arm of the sea, which is now Loch Lomond. Inch Tavannoch and Inch Conachan consist of several ice-worn hummocks of rock, joined

* Adamson, *Mem. Wern. Soc.*, vol. iv.
† *Trans. Geol. Soc., Glasgow*, vols. ii. and iii.

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(Mr. Cunningham Craig.) together by and rising through these marine deposits, which are here and there breached and denuded, and cut into miniature cliffs by the wave action of the present lake.

Rossarden and the northern part of Inch Lonaig are the best localities for the marine fauna. Mr. Alfred Brown, of Broomfield, Luss, has kindly supplied the following list of species, which he collected on Inch Lonaig and identified.

Mya truncata.
Cyprina islandica.
Pecten islandicus.
Mytilus modiolus.
Tellina tenuis.

Though the fossiliferous clay has only been observed at levels below the 50-feet contour-line, the fauna points to cold-weather conditions, and the deposits probably belong to the time of the 100-feet beach.

North of Luss no traces of the marine deposits have been observed on the western shore of the lake. It is possible that the narrower upper reaches of the Loch Lomond were occupied by ice at the time when these sands, gravels, and clays were laid down.

County Wicklow.

(Mr. Nolan.) At such intervals as could be spared from the work of the office in Dublin, Mr. Nolan has continued the mapping of the superficial deposits in the region to the south of Dublin. He finds that the district immediately west of the high ground that extends in a southerly direction from Ballygobban south-east of Lugnaquillia mountain to the heights west of Tinahely is in general a rather flat, moory tract, gently sloping from the hills, at an elevation of from 700 to 800 feet above the level of the sea. Most of it is covered with scattered stretches of peat-bog over drift of local origin, containing pieces of granite and schist. This deposit is sandy or somewhat clayey, passing into a sandy boulder-drift, which, in some of the narrow stream-courses, has been heaped up to a considerable depth. The surface is often encumbered with blocks of granite, particularly in the vicinity of Moyne Church, north of Sandy Ford, and westwards to the borders of Co. Carlow. The limestone-gravel of the plain is met with to the west at High Park, three miles north of Hackettstown, whence it extends southwards, seldom in this district attaining a greater height than about 600 feet.

On the opposite or south-eastern side of the ridge, where there is far less moor and peat-bog, the local drift is usually thicker, and forms long, smooth slopes, well cultivated, and diversified with trees and plantations. In the valley traversed by the railway, between Aughrim and Tinahely, sand and gravel prevail, and a section through these deposits showing rude stratification was noticed at Tinahely railway station. These sands and gravels are of local derivation and contain no limestone fragments.

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Although the rocks in this district are chiefly granite, and consequently little calculated to retain ice-markings, yet some striæ are occasionally seen. In the valley of the Ow, or Aughrim River, one mile south-east from Aghavannagh, striæ may be observed that bear north and south, while at Ballymanus Hill, near Aughrim, and on the heights above Ballinglen, the trend is towards south-east. These scorings, corresponding generally with those observed in northern Wicklow, confirm the conclusion that the direction of the ice flow in this part of Leinster was southerly, inclining to south-east. (Mr. Nolan.)

RECENT.

In the foregoing pages references have been made to some of the Recent formations met with in the course of the field-work last year. In addition to these the following brief notes are here given.

In the district of Sussex between Midhurst and Pulborough, recently mapped by MR. LAMPLUGH, it is noted that as the Lower Greensand of that tract does not afford much gravel-making material, the plateau-drift has formed the chief source of the later valley-gravels. Consequently, although terraces of erosion are sometimes well-marked along the principal valleys, there is usually very little gravel upon them except around the mouths of tributary streams which have eroded the plateau-drift. Impersistent valley-gravels occur here and there along the course of the Rother, at various elevations up to 40 or 50 feet above the present stream. Eastward, towards the junction of the Rother and the Arun, these terrace-gravels attain a wider development, and as the plateau-drift sinks to lower elevations in this direction, there is some difficulty in distinguishing between this drift and the higher patches of valley-gravel. **Sussex. (Mr. Lamplugh.)**

While mapping the older rocks of the south coast of Cornwall, MR. HILL has likewise traced the superficial accumulations which in post-Tertiary time have been formed more especially in the inlets by which these shores are indented. He notes that the upper parts of the tidal estuaries are mostly filled with a deposit of brown mud, formed from the decomposition of the slates, and carried seaward by streams. Amongst these deposits, that of the estuary of the River Fal calls for special notice on account of its being likely to turn out of considerable economic importance. The Fal, for part of its course, cuts through the mass of the St. Austell granite, and receives the drainage of its western portion. As this granite is in a highly decomposed condition, it readily lends itself to the processes of denudation, in striking contrast to the neighbouring slates, which, in comparison, disintegrate slowly, so that the detritus from the granite forms the principal part of the deposit. The decomposition of the felspar has resulted in the formation of deep deposits of argillaceous material, which is mixed with the sand **Falmouth District. (Mr. J. B. Hill.)**

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Falmouth District. (Mr. J. B. Hill.)

and gravel of the estuary, and includes beds of impure kaolin, the deposit of which is now considerably accelerated by the drainage of the waste water from the china-clay works. This water, having a white, milky look, is charged with kaolin of the very finest texture, which has escaped in suspension. The clay of the estuarine deposit is of a white and pale yellow-grey colour. The beds of sand and gravel with which it is mixed consist of the coarser granitic detritus, and are most frequent at the head of the estuary, and along the borders of its channel. A factory has been established on the banks for the manufacture of bricks, which are largely used in the locality, and works are at present being started for the manufacture of earthenware, which, if remunerative, will create a new industry in the district. The clay suitable for this purpose extends for at least a mile along the estuary, and its thickness varies with the shelving of the bottom. It is at present being extracted to a depth of at least 12 feet below high-water mark, and this depth in many parts may be considerably exceeded.

Wicklow. (Mr. Nolan.)

While tracing the Drift-deposits in County Wicklow Mr. Nolan has likewise mapped the extensive tracts of peat-bog of that region. It has already been mentioned that much of the Drift in the moory uplands between Aghavannagh and Tinahely is covered with peat. A good deal of it is thin, and of poor quality, but there are some deep bogs where excellent fuel is obtained. Large tracts of peat-bog cover most of the floor of the valley between Aughrim and Tinahely, that near the latter town and at Ballinglen being much utilised. A considerable extent of mountain bog caps the hill of Ballymanus, at an elevation of 1,200 feet above the level of the sea. Roots and branches of trees, especially of the common birch, are met with in these bogs.

An extensive deposit of river alluvium spreads over all the lower parts of the Aughrim and Tinahely valley, sending arms into the subsidiary valleys. As just mentioned much of its surface is covered with peat.

II.—PETROGRAPHICAL WORK.

Some of the petrographical work of the Survey during the past year has been embodied in the foregoing pages in connection with the narrative of the field-work in the different districts whence the rocks examined have been obtained. But some further account of special petrographical researches has been reserved for the present section of this *Summary*. These researches have embraced both microscopical and chemical investigation. The specimens of which the investigation have been required for the purposes of the maps and memoirs of England and Wales and Scotland have been studied at this museum by Mr. Teall for the microscopical, and by Dr. Pollard for the chemical analyses. Those needed for the Irish branch of the Survey have been examined by Mr. H. J. Seymour at the office

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of the Survey in Dublin. The chief additions to the rock collections of the Survey have been made in Scotland where the Collectors gathered 136 rock specimens in illustration of the geology of the counties of Argyll, Inverness (Skye), Ross, and Sutherland. A number of the rocks collected in Scotland by members of the staff were sliced for microscopic examination, and have been examined and described by MR. TEALL and MR. HARKER.

Jermyn Street Museum. (Mr. Teall.)

The total number of sliced rocks added to the petrological collection at Jermyn Street under MR. TEALL'S charge during the past year is 456. Of these 79 are English, 348 Scottish, and 29 foreign. The foreign rocks have been sliced for comparison or to assist in answering enquiries addressed to the petrological department by public institutions or private individuals.

Detailed reports on 235 rocks have been furnished to the field officers. The remaining specimens have either been dealt with by the field officers or utilised for the purpose of labelling Museum specimens.

The English collection of rock-slides at Jermyn Street now numbers 3,265, the Scottish 8,678, and the foreign, 451.

The final revision and preparation for the press of the petrographical work on the Lewisian gneiss has been completed.

A series of microscopic slides of rocks from British Guiana, forwarded by PROFESSOR J. B. HARRISON, of the Government Laboratory, Georgetown, has been examined and reported upon.

The gradual substitution of the New for the Old Series of one-inch maps has rendered necessary the reclassification of the English petrographical collection. This has been done by MR. RHODES, assistant in the Fossil Department during the past year. All the English and Welsh rocks are now classified according to the New Series of maps.

The principal work in the Rock-room of the Jermyn Street Museum has been the relabelling of the Silurian rocks of Ayrshire and Dumfriesshire, and of the Carboniferous volcanic rocks of Scotland. This work, which has been carried out by MR. RHODES, under MR. TEALL'S supervision, necessitated the preparation of many new and thinning down of old sections, which were unsuitable for precise petrographical determination.

A series of specimens illustrating rock-structure in the Isle of Man, collected by MR. LAMPLUGH, has been added to the structure case in the rock-room.

MR. A. W. CLAYDEN, M.A., F.G.S., Principal of Exeter University College, has presented to the Museum a series of specimens of the Permian volcanic rocks of the Exeter district.

Dublin Office. (Mr. H. J. Seymour.)

In the Dublin Office of the Geological Survey during the past year, MR. H. J. SEYMOUR has examined and reported on 234 thin slices of rocks, while 170 new slides were prepared and added to the Irish collection, which now numbers 2,351. In order to facilitate the preparation of a "rock type" catalogue,

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he also examined and named nearly 100 slides in the collection which had not previously been determined. The report of his work, given on p. 176, is based on the examination of a number of slides selected as representative of about 750 specimens collected in the various districts referred to.

The following summaries of some of the more interesting or important researches of a petrographical kind carried on in the Survey during the past year, have been supplied by the officers who have been engaged in them:

Insoluble Residues of Chalk.

(Mr. Teall.) Insoluble residues, prepared by Mr. William Hill from various horizons in the chalk, have been examined. The results are in accordance with those established by Dr. Hume for the English, and by M. Cayeux for the French Chalk. Quartz and alkali felspars are the principal clastic constituents; but whenever a sufficient quantity of material is available many heavy minerals, such as rutile, zircon, tourmaline, cyanite, and garnet may be detected.

No volcanic minerals and no traces of pumice or volcanic ash were observed; and the general character of the sedimentary material of mechanical origin, so far as composition is concerned, was found to be the same from all horizons. The amount and size of the mineral particles will be dealt with by Mr. Hill as a part of his important work on the comparative petrology of the Upper Cretaceous rocks.

The Volcanic Rocks of the Exeter District.

The preparation of an Explanation of Sheet 325 of the New Series of one-inch maps, embracing the district around Exeter, made it desirable that the petrography of the interesting volcanic rocks lying at the base of the red sandstone of that part of Devonshire should be more fully worked out. This research devolved on Mr. Teall, who has furnished the following summary of the results obtained by him:—

The general relations of these rocks to the sedimentary series has been described by Sir A. Geikie in his work on the "Ancient Volcanoes of Great Britain," and the same work contains also some particulars as to the petrographical characters of the rocks, based on observations by Dr. Hatch and Mr. Watts. Further petrological details are contained in an important paper by Mr. Hobson, "On the Basalts and Andesites of Devonshire."* The general results of the re-examination may be briefly summarised as follows:—The rocks range in composition from trachytes or orthophyres to basalts or melaphyres. Many of them represent effusive forms of the minette-magma, and they

* *Quart. Journ. Geol. Soc.*, vol. xlviii. (1893), p. 496.

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are thus brought into relation with the mica-trap dykes, which have been so well described by Mr. Collins.* (Mr. Teall.)

Most of them are in an advanced stage of decomposition, especially as regards the ferro-magnesian constituents. Augite is often represented by pseudomorphs in carbonate, and olivine has been converted into iddingsite or, in extreme cases, into carbonates and ferric oxide. The oxidation of the iron-bearing compounds gives a predominating red colour to the rocks. Much of this decomposition is of Permian age. It appears to be of the lateritic type so common in tropical regions, and the washing down of the red material by the Permian torrents has contributed largely to the formation of many of the basal rocks of the New Red Sandstone series.

The rock of Killerton Park near Exeter, is a biotite-trachyte or orthophyre having marked affinities with the cuselite (Rosenbusch) of Rhenish Prussia and the orthophyre associated with the lower Rothliegende of Thuringia.

Another type of orthophyre containing numerous pseudomorphs of olivine occurs at Knowle, Spencecombe, near Crediton. Both these rocks have been analysed by Mr. Grant Wilson. They are closely allied to minettes in composition.

The well-known rock of Pocombe, so largely used for building in Exeter, is intermediate between orthophyre and basalt. It is composed of numerous red pseudomorphs after olivine, in a matrix composed of more or less lath-shaped microlites of felspar, a few grains of augite or carbonates after augite, and particles of iron-oxide. Both plagioclase and orthoclase are present, the relative proportion varying in different specimens. The minute and more or less altered laths of plagioclase form kernels in the orthoclase as they do in the absarokites of Iddings.†

The more typical basalts occur in the neighbourhood of Ide and Dunchideock. They frequently contain quartz, and are closely allied to the quartz-basalts of American authors. Mr. Hobson's paper contains a full description of these rocks and a discussion as to the origin of the quartz which he regards as foreign to the magma.

In comparing the Exeter maps with their Continental equivalents, the fact that they are but feeble representatives of the Permian volcanic episode is strongly emphasised. In bulk they are insignificant in comparison with the Permian igneous rocks of Rhenish Prussia (Saar-Nahe-district), the Thuringerwald, and Les Grandes Rousses. Not only is the amount of igneous material much larger on the Continent, but the rocks are also of a much more varied character. In Rhenish Prussia quartz-porphyries, porphyrites (andesites) and melaphyres (basalts) occur in great abundance and in rich variety. Under these circumstances, it is interesting to note that the Permian breccias of

* *Jour. Roy. Inst., Cornwall*, part ii., vol. iii. (1884).

† Absarokite-shoshonite-banakite series, *Jour. Geol.*, vol. iii., p. 935.

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(Mr. Teall.) South Devon contain, as MR. WORTH has shown, quartz-porphyries, rhyolites, spherulitic felsites, and andesite in addition to the rocks above described. The Exeter traps and the Permian breccias taken together probably contain representatives of all the Continental types occurring on this horizon.

CHEMICAL INVESTIGATION OF ROCKS AND MINERALS.

The work of the chemical laboratory at the Jermyn Street Museum has continued to make good progress. DR. POLLARD was instructed, in addition to his duties there, to visit the officers in the field in South Wales in order to study on the spot the phenomena of dolomitization which are developed in the Carboniferous Limestone of that region. Accordingly, he studied these phenomena in the district of the Mumbles and collected material which awaits further treatment. He has conducted in the laboratory a series of quantitative analyses, and has likewise made a considerable number of qualitative examinations for petrographical purposes, or the identification of specimens. He has furnished the following notes of some of the more important researches on which he has been engaged :—

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

During the course of his survey of the Tertiary volcanic region of the Island of Skye, MR. HARKER has met with groups of rock of which it was highly desirable to know the complete chemical composition. He accordingly selected the following series of typical specimens, and submitted them for investigation by DR. POLLARD. The results of the inquiry are here given :—

[7064.] Granophyre, hornblendic, of Beinn a' Chairn sheet, in tributary of Allt Braigh Bhlain, 1,200 yards south-west of triangle on Beinn a' Chairn.

[8057.] Olivine Basalt (sill), Brochbeinn, 500 yards north of small tarn and south-east of larger loch.

[8043.] Olivine Gabbro, west bank of Sligachan River, just below junction with Allt Coire Riabhaich (the northerly burn of that name).

[8194.] Gabbro, Coire a' Mhadaidh.

[7124.] Hornblendic Granophyre, typical drusy variety, south end of Druim Eadhan Da Choire, west side of Coire na Aulg.

[8185.] Olivine Basalt (lava), Altt Feionn Fharadid, Drynoch.

[7854.] Olivine Diabase, sill in bedded basalt lavas, summit of Ben Lee.

[7862.] Porphyritic Olivine Dolerite or Basalt, 7 feet dyke cutting granite on south-east slope of Ciche na Beinne Deirge.

Nos. 7064, 8057, and 8043 were analysed in detail (most of the ingredients mentioned by CLARKE and HILLEBRAND* being looked for). The analytical methods used were those described by these chemists. The remaining five rocks were not analysed in

* *Bull. U. S. Geol. Survey*, No. 184.

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quite so much detail, very small quantities not being determined quantitatively. Tertiary volcanic rocks of Skye. (Dr. Pollard.)

Special precautions were taken as to the purity of reagents, and it was occasionally found necessary to purify some of them. Potassium bisulphate was always prepared in the laboratory owing to the difficulty of obtaining it of a satisfactory quality. Again, hydrofluoric acid has always been redistilled with permanganate before ferrous iron determinations. As it was suggested that some of the rocks from Skye contained metallic iron, Nos. 8057 and 8043 were examined for it by treating with a strong solution of mercuric chloride. The samples for this examination were crushed roughly, wrapped in cartridge paper to avoid any chance of contamination with iron. After all paper scraps had been picked out with care, the coarse powder was crushed and finally ground to a very fine powder in an agate mortar.

Blind experiments with rock-powder + a small weighed quantity (·05 to ·1g.) of pure iron wire were made. These gave good results [the greatest deviation being ·0771g. Fe taken = ·0763g. found], and as 2 to 5g. of rock-powder were taken, the error would be negligible. No iron could be detected in either of these rocks. It might, however, be of interest at some future time to examine a larger number of gabbros and basalts from Skye.

—	7064.	8057.	8043.
S.G.	2·63	2·91	2·85
SiO_2	71·98	46·13	46·39
TiO_2	·37	3·60	·26
ZrO_2	—	Trace?	—
Al_2O_3	13·13	17·07	26·34
Fe_2O_3	1·33	6·61	2·02
Cr_2O_3	—	Trace?	Trace
FeO	1·64	8·20	3·15
MnO	·14	·28	·14
CaO	1·15	7·15	15·29
BaO	Trace	—	—
MgO	·56	4·38	4·82
K_2O	4·93	1·19	·20
Na_2O	2·98	3·58	1·63
P_2O_5	·19	·09	Trace
Cl	Trace?	—	—
H_2O 105°	·39	·59	·10
H_2O above	1·38	1·71	·48
Total - -	100·17	100·58	100·82

[NiO, CoO, Li_2O, S, F were not found.]

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Tertiary volcanic rocks of Skye. (Dr. Pollard.)

—	8194.	7124.	8185.	7854.	7862.
S.G.	2·90	2·66	2·87	2·85	2·95
SiO_2	47·28	70·34	46·61	45·24	44·01
TiO_2	·28	·46	1·81	2·26	1·66
Al_2O_3	21·11	13·28	15·32	15·63	12·69
Fe_2O_3	3·52	2·65	3·49	5·56	3·62
Cr_2O_3	—	—	Trace	Trace	Trace
FeO	3·91	2·24	7·71	7·19	8·75
MnO	·15	·19	·13	·23	·21
(CoNi)O	—	—	Trace	Trace	Trace
CaO	13·42	1·24	10·08	9·38	10·57
MgO	8·06	·40	8·66	7·82	12·86
K_2O	·29	4·90	·67	·72	·49
Na_2O	1·52	3·61	2·43	2·01	1·68
P_2O_5	Trace	Trace	Trace	·20	·17
CO_2	—	—	Trace	·49	Trace
S	—	—	—	—	·11
H_2O 105°	·13	·46	1·10	1·12	·89
H_2O above 105°	·53	·76	2·07	2·21	2·73
Total -	100·20	100·53	100·08	100·06	100·44

No. 7124 contains a trace of BaO and Li_2O.

Culm-measure manganese. (Dr. Pollard.)

An analysis of a manganese deposit of Culm Measure Age from a limestone quarry, Hookworthy, Devonshire, gave the following results :—

Res. insol. in concentrated hydrochloric acid -	64·64
CuO	·15
Fe_2O_3	13·10
Al_2O_3	·72
(NiCo)O	·11
MnO	9·98
CaO	·55
MgO	·20
O (Peroxide Oxygen)	2·05
H_2O at 105°	5·72
„ above 105°	3·21
Total -	100·43

The insoluble residue is composed of—

SiO_2	63·3	of which 2·0% is colloid silica.
Fe_2O_3	·2	
Al_2O_3	·9	
CaO	·3	
	64·7	

The substance was a dark-brown friable powder which required no grinding, but only thorough mixing to get a uniform sample.

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The small quantities of copper, nickel, and cobalt are interesting, as traces of these ingredients were found in the manganese nodules described in the "Challenger" reports. Culm-measure manganese (Dr. Pollard.)

MR. TEALL gives the following account of this specimen:—"The specimen analysed by DR. POLLARD was collected by me, from a Limestone Quarry in the Lower Culm series close to the village of Hockworthy, Devonshire. It was taken from one of several black bands, measuring two or three inches in thickness, regularly interstratified with grey shales, and apparently overlying the limestone. The insoluble residue is a fine white powder, mainly composed of cryptocrystalline silica in minute grains and irregular amorphous patches. A few grains of quartz measuring less than ·1 mm. in diameter, and probably of clastic origin occur, but the amount of mechanical sediment is extremely small. The cryptocrystalline silica is probably of organic origin. The specimen was analysed in the hope that it would be found to be much richer in oxide of manganese than actually proves to be the case. The limestone in the same quarry is dark, bluish-grey, and finely crystalline. Cherty portions of this limestone consist of cryptocrystalline silica associated with calcite which often takes the form of idiomorphic rhombs."

A sample of the clay already referred to as deposited in the estuary of the Fal and as probably of economic importance was sent up by MR. HILL. It was taken from a ford across the Fal, half a mile west of Ruar Lamhorne. A complete analysis of the clay gave the following results:— Falmouth Clay Deposit. (Dr. Pollard.)

AIR DRIED SAMPLE.

SiO_2	49·67
TiO_2	·19
Al_2O_3	33·43
Fe_2O_3	1·92
CaO	Trace
MnO	Trace
MgO	·37
K_2O	3·32
Na_2O	·29
Li_2O	Trace
SO_3	·07
Cl	·37
H_2O 105°	1·30
H_2O above 105° + some organic matter	9·64
	100·57
Less O for Cl	·17
Total	100·40

The chlorine and sulphuric acid are due to sea water.

The soluble salts amounted to ·83 per cent., the sand + acid silicates to 24·7 per cent.

Among the rocks met with by MR. CLOUGH in the Glenelg district is an eclogite, regarding the chemical constitution of one of the minerals of which further information was desirable. Accordingly from a specimen sent up for examination by MR. Eclogite of Glenelg. (Dr. Pollard.)

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Eclogite of Glenelg. (Dr. Pollard.)

CLOUGH the garnet was separated and analysed. The locality given by MR. CLOUGH for the specimen is "½ mile + 60 yards slightly east of north of Beinn a Chapuill," and the following is MR. TEALL's description :—

"[8449.] Medium-grained dark coloured massive rock, composed of garnet and omphacite, with rutile as an unimportant accessory. This rock is a typical eclogite."

The specific gravity of the garnet was 3·74, the composition as follows :—

SiO_2	40·3
TiO_2	Trace
Al_2O_3	21·6
FeO	18·0
Fe_2O_3	1·3
MnO	·7
CaO	7·2
MgO	11·2
Total	100·3

Rock analyses. (Mr. Grant Wilson.)

During the winter of last year MR. GRANT WILSON in Edinburgh made eleven analyses of rocks. The details of these investigations will appear in the memoirs of the Survey.

PETROGRAPHICAL RESEARCH IN IRELAND.

Reference has already been made in previous pages (pp. 71–81), to the petrographical assistance given by MR. H. J. SEYMOUR to the officers who have been engaged in revising the Silurian areas of the south-east of Ireland. The following more detailed and connected summary of his observations has been prepared by him.

Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

In the account of the work of the Geological Survey for 1898* a brief statement was given of some general results of a preliminary examination of the igneous rocks and so-called "ashes" in the district lying to the west of the range of the Leinster granite. Early in the past year a more detailed investigation of the rocks of that district was made (Sheets 111, 112, 120, 128, and 129 of the one-inch map), which has confirmed the conclusion that the so-called ashes in this district, which occur within a zone about a mile in width next the granite, are really more or less metamorphosed basic igneous rocks, while those which lie further west are without exception schistose grits or greywackes. The main road which starts just north of "Brittas Big" (top of Sheet 120) and runs southwards through Blessington, Poulaphuca, Annalecky, and Stratford, may serve as boundary line between the two classes of rock. The grits (greywackes) belong to one type and vary only in degrees of coarseness; most of them show a schistose structure. A thin section of a coarse variety, such as occurs near Poulaphuca, is seen under the microscope to consist essentially of quartz-

* *Summary of Progress* for 1898, p. 64.

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grains, showing strain-structure, and forming eyes which are wrapped round by shaly bands of a greenish (chlorite) colour. Pieces of plagioclase crystals are almost always present, but only sparingly: and also rounded and lenticular fragments of finely crystalline basic rocks of the andesite type. The average diameter of the quartz-grains and other component fragments is nearly 4 mm. for this coarse variety, but elsewhere descends to microscopical dimensions. Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

The igneous rocks which have been mapped as "ashes" may be classed together as altered basic andesites (frequently porphyritic) or dolerites without olivine. Where they lie close to the granite mass, they have been metamorphosed into hornblende-schists and amphibolites, while their outcrops at a greater distance appear as mostly epidiorites. This latter type is extensively developed in the north-east corner of Sheet 120 and in the adjoining areas in Sheets 111 and 112. The rock (I. 1848) at Ballinascorney Gap (Sheet 112) may be regarded as representative. It is an altered dolerite of medium grain. Though it looks fairly fresh in the hand-specimen, yet in section the ferro-magnesian mineral is seen to be mainly of secondary origin. The felspars occur in rather fresh lath-shaped sections which are repeatedly twinned. The interior of the crystals of felspar is more basic than the exterior and extinguishes at a higher angle, the passage between the two being sometimes quite gradual and occasionally abrupt. The central portion seems to be labradorite, while the exterior corresponds probably to andesine. The porphyritic constituent is a felspar too highly altered for determination. The augite when fresh is of a pale, reddish-brown colour, but it is for the most part altered into a greenish hornblende. It forms rounded grains, and sometimes fairly large crystals in which the felspar laths are set ophitically. Skeleton crystals of ilmenite occur, but no olivine could be detected.

The hornblende-schists and amphibolites are of the usual type, and call for no special remark. They are extensively developed in the district, and no doubt represent originally pyroxenic varieties. Near Colvinstown a basic mass (Ds, "Greenstone-ash" on Map) occurs, completely surrounded by granite, which sends numerous veins into it. A hornblende-schist which is seen here is composed of alternating narrow bands of actinolite and felspathic material, the whole rock being much folded and contorted. Near Donard (Sheet 129) an interesting outcrop occurs illustrating the effects of dynamo-metamorphism. Ballymooney Hill, north of Donard, and Deerpark Hill, south of the same place, are composed of a coarsely porphyritic rock mapped as "Greenstone-ash." Sections prepared from different parts of the masses show the following characteristics:—

Slide I. 1860 (Deerpark Hill) is the least altered of the series of rocks, but at the same time is considerably metamorphosed as compared with its original condition, when it was most probably a porphyritic basic andesite or aphanite, similar to the well-known Lambay porphyry. In the hand-specimen the por-

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Silurian Rocks West of the Leinster Granite. (Mr. Seymour.)

phyritic plagioclases, which stand out conspicuously on a weathered surface, either singly or in groups of several individuals, form stumpy, flattened prisms of all sizes up to about 2 cm. × 1 cm. × ·5 cm. They seem fairly fresh, show parallel twin striae, and are brownish in colour, owing to various inclusions. In section the ground is mostly made up of minute brown mica-flakes (secondary biotite), along with some uralitic hornblende, embedded in a clear granular felspathic mosaic. Both the mica and the hornblende are oriented in the same direction by pressure, which has given the ground a schistose structure, and caused it to flow round the porphyritic plagioclases, and even penetrate them along cracks. The felspars are much clouded by opaque whitish inclusions. In all cases they show strain-slip, and are usually surrounded by a mylonitic envelope derived from themselves. Chlorite and iron-ore are present, but sparingly. Alteration is too far advanced to determine the plagioclase, but the presence of secondary calcite would seem to indicate a lime variety, very probably labradorite. (This is the felspar in the Lambay rock.)

I. 1861 shows a further stage in the metamorphism of the rock. The bronzy brown mica is still more conspicuously developed. Hornblende is practically absent, and the felspars are beginning to assume a parallel position with regard to one another. Continued strain has made the fragments into which they were broken slide over one another, producing schistose felspathic zones along the gliding planes, and also wavy extinction under crossed Nicols. Weathered specimens now show the felspars up to 3 cm. in length, but with the cross section considerably reduced in area, and arranged with their longest axes parallel to one another, and to the direction of schistosity.

I. 1862 is practically identical with the last, but contains some apatite. The plagioclases become more and more elongated, till the original stumpy crystals are drawn out into lenticles up to 8 cm. long, 1 cm. wide, tapering at each end, and from 1 to 1·5 mm. thick.

I. 1859 is a section of a rock in this stage which is accompanied by the formation of numerous secondary minerals. The brown mica occurs in knots, the individual crystals of which are considerably larger than usual. The felspar has partly recrystallised in water-clear granules, whilst most of the area formerly occupied by it is now crowded with minute prisms of epidote and zoisite. The original ilmenite is represented by sphene which occurs in numerous strongly pleochroic reddish crystals. In this final stage the rock is a banded gneiss or schist composed of white (felspathic), and dark (biotite) bands. The light bands vary in dimensions, according as they represent a single crushed felspar or a group of several individuals, being naturally larger in the latter instance. This case is a remarkably clear demonstration of the effects of metamorphism, and seems to throw some light on the production of banded gneisses. Although the outcrops occur close to the granite mass, no evidence of injection of the latter rock into the basic variety was noticed in this particular case.

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With such clear evidence of pressure metamorphism, there can be little doubt that the hornblende-schists in this locality owe their origin to the same cause, especially as many of them are obviously crumpled and contorted (*e.g.*, at Colvinstown).

County Wicklow. (Mr. Seymour.)

The revision of the igneous rocks in county Wicklow was continued during the year, and some eighty-five slides from Sheet 130, and forty-two from 139 were examined and reported on. Many of the felsites are compact, schistose, and altered; so that their determination is rather difficult and unsatisfactory. As the microscope frequently fails to give much assistance, reliance has to be placed entirely on the field-evidence and on physical and chemical observations. The varieties met with include potash- and soda-felsites, diabases, diorites, dolerites, and basalts, all of which occur both in the uncrushed and crushed condition. The felsites vary much in physical characters, often closely resembling cherts. Thin sections, however, usually reveal the presence of minute plagioclases, in a ground presenting a devitrified aspect. Soda-felsites or keratophyres frequently occur in the area examined. They appear to be the latest rocks in the igneous series, as where typically developed they penetrate the ordinary (potash) felsite, which is known to be later than the basic rocks with which it is associated.

Reference has already been made to the field-observations by Messrs. Egan and McHenry regarding the occurrence of a remarkable brecciated structure in some of the intrusive felsitic rocks in the East of Ireland. Mr. Seymour contributes the following description of one of these which appears near Rockfield House, on the shore south of Wicklow Head. (Sheet 130, I. 1760 and 1761.) Here a greenish trachytic (soda) felsite is seen to penetrate, in numerous veins, a pale-coloured felsite, somewhat more acid perhaps in composition, and which weathers to a pinkish colour. The older rock has been shattered and in one part of its mass, occurs in angular fragments embedded in a greenish base composed of the later intrusive rock, the whole forming an eruptive or intrusive breccia. Continued pressure has subsequently fractured both this base and the included fragments. Microscopically, the greenish "ground" is remarkable. It contains numerous clear fragments (devitrified glass) with concave outlines and hour-glass forms, exactly similar in appearance to the lapilli of volcanic glass so characteristic of tuffs. Figure 48, p. 262, in Rosenbusch's "Elemente der Gesteinslehre" exactly represents the structure developed in the ground of this rock, and could have been drawn from a thin slide of it. There can be little doubt here, however, that the tuff-like structure has been produced by the brecciation in situ of the intrusive veins which had consolidated in a glassy condition, the resulting pieces of fractured glass being similar in shape to volcanic lapilli. Similar "intrusion breccia" occurs also at Arklow Head, Co. Wicklow, where a brecciated rock undoubtedly behaves as a dyke. It consists of pieces of lavender-grey felsite, embedded in a greenish porphyritic and brecciated soda-felsite, the phenocrysts being albites and soda-orthoclase. Though these crystals show evidence

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County Wicklow. (Mr. Seymour.)

of being fractured in situ, it is remarkable that in one of the slides an irregularly-shaped piece of pumice occurs, which could hardly have escaped destruction if it existed during the period of strain to which the rock has certainly been subjected. It seems difficult to account for its presence unless it be regarded as of secondary origin, and possibly somewhat analogous in its formation to the pumice which BERGEN and BEUDANT have shown to be occasionally formed when volcanic glass is gradually fused in a Bunsen flame. The light coloured felsite-fragments, which occur as inclusions, contain sphene, and this has given rise to anatase, which in some of the rocks abounds in crystals of minute size.

As mentioned in last *Summary of Progress*, the rocks mapped as tuffs (Fs or Ds), to the east of the Leinster granite, were found to be sheared varieties of acid and basic rocks respectively. This has again been found to hold for all the ground examined last year. Up to the present no true tuff of any description has been met with in County Wicklow (Sheets 130 and 139).

County Waterford. (Mr. Seymour.)

Some account has been given at p. 79 of the igneous rocks of the coast of Waterford, mapped last year by MR. KILROE. Their petrography has been partly studied by MR. SEYMOUR, who during a visit to the ground with MR. KILROE collected a representative series of the rocks. These have subsequently been examined microscopically, and have been found to be in general similar to those in County Wicklow. Typical soda-felsites occur, some of which in the field closely resemble basic rocks. In section these are seen to be very trachytic in structure, they contain orthoclase (soda ?) phenocrysts, embedded in a crystalline felt of felspar microlites, showing flow-orientation. Secondary chlorite is also present in the slides. The soda-felsite at Ballydowane Bay seems to approach to the pantellerite type. The felsites also frequently show beautifully developed flow, perlitic, and spherulitic structures, being thus rather a contrast to the Wicklow specimens, where these characteristics are only rarely met with.

Another peculiar feature in the rocks of this district is the abundance of secondary epidote which many of them contain. This mineral often forms close on 40 per cent. of the bulk of some of the sedimentary rocks; it also occurs in oval concretions up to 3 in. in longest diameter in a crystalline rock, apparently an altered andesite, near Carrickbarrahane House. A coarsely porphyritic felsite occurs near Ballyvoyle Railway viaduct, containing well-formed, reddish-coloured orthoclase crystals in a greenish felsitic base. The andesites in this area are usually much altered, and the porphyritic mineral, when present, is augite, and not a felspar, as is usually the case in more northerly localities.

Coast of County Down. (Mr. Seymour.)

As already stated, MR. SEYMOUR accompanied MR. EGAN to the east coast of Co. Down, in order to revise the igneous geology of that district (Sheets 37, 38, and 49). Almost every outcrop was visited by them, and a representative series of specimens was collected. These have now been sliced and

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examined by MR. SEYMOUR, who finds them to be all lamprophyres, the varieties differing from one another in the fact that the predominating ferro-magnesian constituent is sometimes biotite, sometimes hornblende, less often augite. In the last case the augite accompanies the biotite or the hornblende, but does not occur to the exclusion of either of these minerals. The felspar, as is usual in these rocks, is much altered and calcified, and is on the whole plagioclase, though a little may be referred doubtfully to orthoclase. The mica varieties are, therefore, Kersantites and augite-Kersantites, and the hornblende varieties Camptonites and augite-Camptonites

Coast of County Down. (Mr. Seymour.)

One of the rocks occurring as a dyke on the shore of South Bay, 3 miles E. of Portaferry (Sheet 49) is specially noteworthy. It is a hornblende-kersantite containing a blue amphibole, allied to riebeckite or arfvedsonite. It belongs to a class of minerals (soda-amphiboles) not hitherto known to occur *in situ* in Ireland, and is now recorded for the first time. The mineral in question occurs as a secondary addition to the terminal edges of the primary green hornblende. A nearly identical occurrence has been described by DR. WHITMAN CROSS in the case of a rock from Colorado.*

Ox Mountain District. (Mr. Seymour.)

An examination of the interesting rocks of the Ox Mountains undertaken by MR. SEYMOUR last year was continued at intervals. Owing, however, to the necessity of completing more urgent work it was not found possible to examine more than a small part of the collection. It is hoped that during the present year the work may be resumed and extended. The varieties examined included felspathic eclogites, garnet amphibolites, schistose diorites, biotite- and hornblende-gneisses, and granites with microcline. They are similar to the rocks described by MR. TEALL from the Ballyshannon area, in the Appendix to the Memoir on the Sheets 31 and 32.

Photographic Work. (Mr. Seymour.)

During his visits to the field in the past year MR. SEYMOUR took a number of photographs of geological interest. One series illustrates some of the typical features exhibited by the rocks along the coast of Waterford, from Stradbally to Annestown. Copies of these are preserved in the office for reference. Some photo-micrographic work has also been done during the year in the case of slides of special interest in the Irish petrographical collection.

III.—PALÆONTOLOGICAL WORK.

The Palæontologists of the Geological Survey at Jermyn Street have charge not only of the palæontological work of the Survey, but also that of the Museum. They determine all fossils collected by the staff in England and Wales and Ireland. The Scottish palæontological work is done at the Survey Office in

* *American Journ. Science*, vol. xxxix., p. 359.

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Edinburgh. Mr. E. T. Newton has supplied the following notes of the more important examinations made by him and his staff last year.

Museum, Jermyn Street.

The constant need of revision and rearrangement of the fossils exhibited in the Museum of Practical Geology, as well as their maintenance in a satisfactory condition, together with the specific determination of such fossils as are presented, received from the field officers, or obtained from other sources, necessarily occupies the greater part of the time of the Palæontological Department. This routine work, however important in itself, is not usually of such a nature as to call for any special remarks; but it may be mentioned that of the fossils received during the year, a large part has already been specifically determined by Dr. F. L. Kitchin, who has likewise named a series of Carboniferous Limestone Cephalopoda, from the Isle of Man, kindly lent to the Survey by Miss Birley and Mr. Robt. Law, to whom our thanks are due for their courteous assistance. We have also to acknowledge our indebtedness to Mr. G. C. Crick of the British Museum for his valued help in the determination of these Cephalopoda.

The results of much of the detailed work of the past year will be seen in the Memoir by Mr. A. J. Jukes Browne on the Gault and Upper Greensand, and in that by Mr. G. W. Lamplugh on the Geology of the Isle of Man, now in the hands of the printer, as well as in other Memoirs which have appeared during the year.

The revisions and rearrangements which have been made in the Museum have chiefly been the work of Mr. H. A. Allen, who has also named a large number of the new fossils added to the collection. The need for a catalogue of the many valuable *figured* specimens contained in this Museum has long been felt; but the pressure of other work has hitherto prevented its being attempted. A beginning, however, has been made by Mr. Allen, who has prepared a catalogue of the *figured* specimens from the Eocene and Oligocene formations. This catalogue includes many of the Types described by Prof. Morris in Forbes's "Tertiary Fluviomarine Formations of the Isle of Wight"; by Prof. Forbes, in "Note on Fossil Leaves from Ardtun"; by De la Harpe and by Mr. Starkie Gardner, in their works on the Plant Remains of the Isle of Wight and of the South Coast. (See Appendix to the present volume, p. 195.) Although but a small instalment, it will serve to show the nature of the work; and being complete, so far as it extends, will, it is believed, be found useful to those working at Tertiary Palæontology.

Three series of Graptolites have been received from the Irish Survey, and reported upon by Mr. Newton. One series was from numerous localities in the Keeper Hill district. The chief forms noticed were of the *Monograptus Flemingi* and *M.*

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Hisingeri types, with some indistinct specimens which appeared to be *Cyrtograptus lamatus*, thus indicating beds of Wenlock or Tarannon age. A few specimens from a cutting on the Waterford, Dungarvan, and Lismore Railway proved to be *Diplograptus* allied to *D. pristis*, and probably indicate the presence of Llandeilo rocks at this place.

A second series from Balyhelly, Co. Clare, too poorly preserved to give positive evidence, seemed to include *Monograptus Flemingi* and *M. priodon*, making it probable that the beds are of Upper Silurian age, and perhaps Wenlock.

A third series, chiefly from the neighbourhood of Belvoir, Co. Clare, were apparently from one horizon only. The absence of any Monograptids made it unlikely that these beds were of Upper Silurian age, and as there were no examples of Didymograptids they could scarcely be so low as Lower Llandeilo. The forms recognised were *Diplograptus pristis*, *D. foliaceus*, *Climacograptus scalaris*, and *Glossograptus Hincksi*, all species of Glenkiln or Hartfell age. It seems almost certain, therefore, that the strata belong to the Lower Bala or Upper Llandeilo series.

Application is constantly being made to this Department for assistance in work of a palæontological nature, and the officers do their best to render such help as is possible. As examples of this co-operation the following cases may be mentioned:—

Sir Thos. Wardle, of Leek, desired information respecting a series of bones, which he had unearthed while exploring a cave at Red Hurst, near Wetton. Two consignments of these remains were examined by Mr. Newton; they proved to be largely human and of comparatively modern origin; perhaps Romano-British, or Neolithic; but there were indications of Pleistocene gravels underlying the more modern deposits. An account of this cave was published by Sir Thos. Wardle in *The Leek Post*, February 25, 1899.

A collection of bones from a deposit at Skitts Hill, Braintree, Essex, was critically examined by Mr. Newton, at the request of the Essex Field Club, as it was deemed desirable to have the specific identification of the bones verified before publication. An account of these remains is included in a paper by the Rev. J. W. Kenworthy on this "Supposed Neolithic Settlement at Skitts Hill," just published in the *Essex Naturalist*.

A series of fossil shells and rocks was received from Judge Middleton of Nicosia, Cyprus, through the secretary of the Royal Societies' Club. The rocks were examined by Mr. Teall, and the fossil shells by Mr. Newton. The deposit from which the shells were obtained appears to be of late Pliocene age. Among the species recognised were many like those found in similar deposits in Italy and Sicily, as well as at other places around the Mediterranean coasts.

The Museum collection of fossils has been largely made use of by workers for the purpose of illustrating their Memoirs, and many specimens have been figured in various publications, as shown in the subjoined list of figured specimens published during 1899:—

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Specimens figured in the Palæontographical Society's volume for 1899, by PROF. RUPERT JONES and DR. H. WOODWARD in their "British Palæozoic Phyllopoda":—

Gastric teeth of Dithyrocaris.
Dithyrocaris tricornis, Scouler.
„ *Colei*, Portlock.

Specimens figured in the Palæontographical Society's volume for 1899, by DR. WHEELTON HIND, in the "British Carboniferous Lamellibranchiata":—

Edmondia oblonga, Portlock.
„ *laminata*, Phillips. Two specimens.
„ „ var. *sublævis*, Hind.
„ *scalaris*, M'Coy.
„ *MacCoyi*, Hind.
Scaldia benedeniana, de Ryckholt.
Cypricardella parallela, Phillips.

Specimens figured in the Palæontographical Society's volume for 1899, by HENRY WOODS, ESQ., in his "Cretaceous Lamellibranchiata of England":—

Nucula speetonensis, Woods.
„ *pectinata*, Sow. var. *cretæ*, Gardner.
„ *obtusa*, Sow. Two specimens.
„ *ibensis*, d'Orb.
Anomia lævigata, Sow. Three Specimens.
„ *cf., pseudoradiata*, d'Orb.
Barbatia marullensis, d'Orb. Two specimens.
Grammatodon carinatus, Sow.
Isocarca obesa, d'Orb.
Pectunculus sublævis, Sow.
„ *umbonatus*, Sow.

Specimens figured by Dr. A. SMITH WOODWARD, in the "Proceedings of the Geologists' Association," vol. xvi., 1899:—

Notidanus serratissimus, Agassiz.

Specimens figured by E. T. NEWTON in the "Quarterly Journal of the Geological Society, London," vol. lv., 1899:—

Amia anglica, Newton.
„ *Colenutti*, Newton.
Zanclodon cambrensis, Newton.
Mustela robusta, Newton.

Specimens figured by MISS DONALD in the same journal:—

Hormotoma ? gracillima, Salter.
„ *? dubia*, Donald.

Specimens figured by H. BOLTON, ESQ., in the "Memoirs of the Manchester Literary and Philosophical Society," vol. xliii., 1899:—

Palæochorda minor, M'Coy. Three specimens.
„ *major*, M'Coy.
Chondrites informis, M'Coy. Three specimens.

SCOTLAND.

The Palæontological Department in Scotland has been carried on as hitherto by MR. B. N. PEACH, assisted by MESSRS. A. MACCONOCHIE and D. TAIT. As usual the collections made during the year, after a preliminary investigation by MR. PEACH, have been partly distributed among specialists for identification and

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description. Thus DR. TRAQUAIR has determined the fish-remains, MR. KIDSTON has undertaken the naming of the plants, MR. KIRKBY has examined the ostracods while DR. J. WHEELTON HIND has examined the lamellibranchs.

The number of fossils gathered by the Survey Collectors in Scotland during 1899 amounted to 913. These comprise 479 specimens from the Cambrian rocks of Skye, Sutherlandshire, &c.; 20 from the Ludlow rocks of Lanarkshire; 112 from the Downtonian strata of Ayrshire and Lanarkshire; 8 from the Lower Old Red Sandstone of Arran; 39 from the Carboniferous Limestone of Arran; 99 from the Coal-measures of Arran and Dumfries-shire; 154 from the Jurassic rocks of Skye, and 2 specimens from Islay.

MR. PEACH has supplied the following digest of the palæontological work of the staff in Scotland for the past year.

Torridonian.—In view of the forthcoming Memoir on the North-West Highlands a further determined search was made by MESSRS. MACCONOCHIE and TAIT in the Torridonian rocks of Skye, chiefly in the dark carbonaceous Shales of the Kinloch sub-division of the Diabeg group. Though the material searched seems eminently favourable for the preservation of organisms, as ripple-marked and rain-pitted surfaces are plentiful, no vestige of a fossil was obtained. The same collectors also made another exhaustive search of the dark calcareous shales of the Cailleach Head in West Ross-shire, the highest visible members of the formation. The only indications of life they there exhumed are some doubtful specimens of annelid castings ("Worm pipes"), but these are not sufficiently definite for identification. The shales of the Diabeg Group at Stoer in West Sutherland, which had already afforded some traces of organisms, were also searched bed by bed with the result that only the curious radiating bodies resembling some sponge spicules were obtained. The further study of some of the specimens, however, throws some doubt upon the organic character of these bodies. They may not be organic, but may be due to aggregations of crystals that had formed in the clays before their consolidation, but had been subsequently dissolved out and replaced by calcite. It is unfortunate that hitherto the Survey Collectors have been able to obtain no more definite organic remains than "worm pipes" from these practically undisturbed sediments.* (Mr. B. N. Peach.)

Cambrian.—A further collection of fossils was made by MESSRS. MACCONOCHIE and TAIT from the Durness limestones and dolomites in the Strath district of Skye. The search was made chiefly for the purpose of obtaining remains of trilobites

* Since the above notes were written, certain phosphatic nodules occurring in the dark micaceous shales at Cailleach Head have been examined by MR. TEALL. From their chemical composition these nodules are presumably of organic origin, an inference which is confirmed by the fact that MR. TEALL has determined under the microscope certain spherical cells and brown-coloured fibres in them, which appear to be débris of organisms.

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(Mr. B. N. Peach.) that might have a zonal value for the determination of the exact geological horizon of the members of the Durness Limestone series. Although a considerable collection of fossils was obtained no trilobite remains were found among them. The fossils add little or nothing to the list furnished in last year's *Summary*. A search was likewise made in the Durness area of Sutherland, where the collectors succeeded in finding several fragments of trilobites. From the preliminary study of the material thus acquired, the fossils would seem to indicate that the Croisapuill group of the Durness Limestone, the bed in which they chiefly occur, is of Middle or Upper Cambrian age—a conclusion to which the study of the other fossils from this band has already led.* Fragments of *Olenellus* were obtained from the cleaved 'Fucoid Beds" near Heilim, on Loch Eireboll, by MESSRS. MACCONOCHIE and TAIT. This is the first record of trilobites from this region, which is classic in the history of the rocks of the North-West Highlands.

Silurian.—A further search was made by MR. TAIT in the Ludlow and Downtonian rocks of Ayrshire and Lanarkshire, with the result that fragments of the fish *Birkenia elegans*, hitherto only obtained from the Downtonian rocks, was got in the *Ceratiocaris*-band of the Ludlow rocks on the Logan water above Lesmahagow. The materials obtained from the Downtonian rocks have been studied by DR. TRAQUAIR, and the results have been embodied in a paper published by him.† He remarks that, "Two additional specimens of *Lasanius*, collected by MR. TAIT at Seggholm since my notes at p. 567 were in type, indicate a new species distinguished from *L. problematicus* by the considerably greater proportional size and length of the spurs or thorns borne by the median scutes, and which I propose to designate *Lasanius armatus*. In one of these two examples the rays of the acutely bilobate heterocercal tail are preserved, the arrangement of which furnished the long desired clue to the position of the median row of scutes, proving that they were placed along the ventral margin of the body. Consequently it is now very improbable that the gridiron-like arrangement of ossicles in the anterior part of the body had anything to do with the support of the branchiæ."

Old Red Sandstone.—Further remains of plants were obtained from a new locality in the Lower Old Red Sandstone of Arran on the south side of Glen Rosie not far from the boundary fault. In going over the material obtained by him last season from the Lower Old Red Sandstone exposed in the railway cutting about a mile from Oban, MR. TAIT observed the casts of what appeared to be ostracods. Some specimens were sent to MR. JAMES W. KIRKBY, who confirmed this identification. The fossils were subsequently submitted to PROFESSOR RUPERT JONES who refers them to the genera *Aparchites, Isochilina,*

* *Summary of Progress* for 1898, p. 55.

† *Transactions of the Royal Society of Edinburgh*, vol. xxxix., pp. 827-864.

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and *Beyrichia* (*?*), or *Drepanella*, one of the latter being curiously like the *Beyrichia* (*?*) *Holli*, Jones. Along with these casts occur the remains of *Cephalaspis* and *Pterygotus*. Although ostracods are plentiful in the Devonian Rocks of the South of England and the bivalve phyllopod *Estheria* is common in the Caithness flags, this is the first recorded instance of undoubted ostracods having been found in the Lower Old Red Sandstone of Scotland. (Mr. B. N Peach.)

Carboniferous.—A further collection of Carboniferous fossils from the streamlet flowing into the Sliddery Water at Sliddery Water Head was made by MR. TAIT last season. The discovery has already been announced of *Carbonicola* (*Anthracosia*) *acuta*, together with fish remains in this section,* the general facies of the organisms indicating the horizon of the true Coal-measures. With these remains there were also discovered fragments of plants characteristic of the Lower Carboniferous subdivisions. The fossils collected this season help to define more precisely the boundary-line between the Upper and Lower Carboniferous rocks in this section. The evidence afforded by the various bands exposed in the Sliddery Water may be tabulated as follows in descending order.

4. Fine red mudstones, with numerous specimens of *Neuropteris heterophylla*, a characteristic Coal-measure form, and a specimen of *Spirangium carbonicum* (Schimper), supposed at one time to be a plant, but now thought to be the egg capsule of a placoid fish, and known as *Palæoxyris carbonicus*. This form has hitherto been recorded from only one other locality in Scotland, Woodhead Quarry, near Kilmaurs, Ayrshire, in strata belonging to the lowest members of the Coal-measures.

3. Thin mussel-band ironstone (2-3 inches) charged with *Carbonicola* (*Anthracosia*) *acuta* and *C.* (*A.*) *robusta*.

2. Grey and red shale yielding the following fishes:—*Platysomus parvulus*, *Megalichthys Hibberti*, *Rhizodopsis sauroides*, *Strepsodus sauroides*, *Diplodus sp.* *Pleuroplax sp.* *Helodus sp.* together with the plants *Lepidodendron veltheimianum*, *Lepidostrobus*, *Stigmaria*, and *Calamites*.

1. Red tuff, containing chiefly calamites, the most abundant form being *Astrocalamites scrobiculatus*, a characteristic Lower Carboniferous form.

It thus appears that, the fossils of bed or zone 1 are characteristic of the Lower Carboniferous formations (*i.e.*, Calciferous Sandstone and Carboniferous Limestone series); those of bed or zone 2 show a commingling of forms belonging partly to the Lower and partly to the Upper Carboniferous divisions, while those in beds or zones 3 and 4 are confined to the upper division (*i.e.*, Millstone Grit and Coal-measures). It is evident, therefore, that bed or zone 2, represents palæontologically the passage-zone between the two great divisions of the Carboniferous system.

Rhætic.—The specimens obtained from these zones in Skye by MESSRS. MACCONOCHIE and TAIT, were forwarded to Jermyn Street, where they have been examined by MR. NEWTON and DR. KITCHIN as stated on p. 133.

The palæontological collections of the Survey of Scotland have

* *Summary of Progress* for 1897, p. 113.

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(Mr. B. N. Peach.) been freely placed at the disposal of experts engaged in working out any of the groups of fossils there represented. These collections are, as far as possible, displayed to the public in the gallery assigned to the Survey in the Edinburgh Museum of Science; some of the specimens are necessarily still retained at the Survey Office for purposes of study and comparison. Among those who have made use of the Scottish specimens collected by the Survey, reference may be made to Miss Donald, who has figured and described (*Quart. Journ. Geol. Soc.*, vol. lv., 1899), several specimens of Cambrian gasteropoda from the Durness limestone. These are :—

Ectomaria pagoda, var. *Peachi*. Plate xxi., figs. 1 and 2.
„ „ var. *orientalis*. Plate xxi., figs. 3 and 4.
Hormotoma antiqua. Plate xxii., fig. 9.

Dr. Wheelton Hind has named for the Survey a large number of Lower Carboniferous lamellibranchs from Liddesdale, and has also figured and described in a Monograph of the British Carboniferous Lamellibranchiata (*Palæontographical Society's Publications*, 1897), the following species :—

Myalina sublamellosa. Plate v., figs. 6, 7, 8.
Nuculana Sharmani. Plate xv., figs. 19–22.
„ *stilla*. Plate xv., figs. 24, 25.

Dr. Traquair, in addition to writing the important Memoir on the Silurian fishes belonging to the Geological Survey already referred to, has revised the nomenclature of the specimens of fossil fishes exhibited in the Museum. He also transferred on loan from the Natural History section to the Geological Survey cases several duplicate specimens of fossil fishes from the Caithness flagstones. These form a useful supplement to the specimens already in the Survey collection. Dr. Traquair has also presented to the Survey a set of his figures of the new Silurian fishes, while Mr. Newton has given copies of the plates that illustrate his Memoir on the Elgin Reptiles.

Mr. Kidston has revised the nomenclature of the Carboniferous plants exhibited in the Survey collection in the Museum.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

Applications for information on geological matters have, as usual, been numerous at the offices of the Survey in London, Edinburgh, and Dublin. From the London Office assistance has been afforded to the Local Government Board, the Colonial Office, and the Agent-General for New Zealand. Advice on various subjects connected with mining, well-sinking, soils, sites for houses, &c., has been given as far as possible, personally and by letter, to those who have sought for information.

It has been suggested by the Local Government Board that it would be much to the public advantage if arrangements could

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be made whereby, on the request of the Board, officers of the Geological Survey should be sent to examine and report on any district where particulars might be required by that Department relating to water supply, the pollution of springs, sites for burial-grounds or sewage-farms, or other subjects where precise geological information is necessary. The matter is now before the Lords of the Committee of Council on Education, and it is hoped that the suggestion will be carried into effect.

At the Edinburgh Office of the Survey the number of applications by the public for information of a practical kind where geological knowledge is involved have been larger than in preceding years. They comprise enquiries relating to the position of coal-seams, limestones, ores, suitable building stones, &c., and also questions of water-supply, and the character of subsoils. As an illustrative example reference may be made to enquiry by Dr. Aitken, Medical Officer of Health, Brighton, regarding the nature of the rocks and sub-soils of Edinburgh in connection with a Report on the comparative prevalence of diarrhœa on certain soils in several of the larger towns of the country. The desired information was prepared and furnished.

At the Dublin Office also, constant applications continue to be made in regard to geological information of an economic kind. Many of these have reference to mines and minerals, especially to coal and metalliferous ores. But in Ireland, as in the sister kingdoms, the most frequent subject of enquiry is that of water-supply. During the past year the reports in answer to these demands have sometimes been necessarily of a detailed character, and have involved the drawing of sections in explanation of the geological structure of the ground. Among the public departments that have availed themselves of Survey assistance in such matters were the War Department and the Congested Districts Board of Ireland.

V.—MAPS, MEMOIRS, SECTIONS, &c., PUBLISHED DURING 1899.

A.—OFFICIAL.

I.—MAPS.

1.—*England and Wales.*

New Series of One-inch Maps.—Seven sheets of the New Series of one-inch maps have been published during last year, viz.:—

Sheet 155, Atherstone. Two editions with and without Drift. By C. Fox-Strngaways and W. W. Watts (Charnwood).

Sheet 282, Devizes. One edition with Drift. By F. J. Bennett and A J. Jukes-Browne.

Sheet 315, Southampton. One edition with Drift. By W. Whitaker and C. Reid.

Sheet 325, Exeter One edition with Drift. By W. A. E. Ussher.

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Sheet 339, Newton Abbot. One edition with Drift. By H. B. Woodward, W. A. E. Ussher, and C. Reid.

Sheet 340, Otterton. One edition with Drift. By W. A. E. Ussher.

Sheet 349, Ivybridge and Plymouth. One edition with Drift. By W. A. E. Ussher.

Old Series of One-inch Maps.—Sheet 19. Revised with Additions, by H. B. Woodward and A. Strahan.

The following One-inch New Series maps are in the hands of the engravers:—187, 203, 231, and 316.

Plans for printing these maps in colours are under consideration.

Six-inch Maps.—Northumberland. — Sheet 104, Whittonstall. By H. H. Howell.

Yorkshire.—Sheet 19, Hinderwell. By G. Barrow.

Six-inch Reference Maps.—96 MS. Coloured Copies of six-inch sheets and quarter-sheets have been made from the field-copies and deposited in the office for public reference. These are as follow:—

Brecknockshire.—31 S.E.; 32 S.W.; 37 N.E., S.E.; 38 N.W., S.W. 43 N.E., S.E.; 50 N.W.
Derbyshire.—57 N.E., S.E., N.W., S.W.; 58 N.E., S.E., N.W., S.W.; 60 N.W.
Devonshire.—105 N.E, S.E.; 106 N.E., N.W.
Dorset.—30 S.E.; 39 S.E.
Glamorganshire.—9, 11, 16, 41, 44, 45, 48, 49.
Hampshire.—48, 57, 64, 65, 66, 67, 73, 74, 75.
Leicestershire.—5 S.W.; 10 S.E., N.W., S.W.; 15 N.E., S.E., S.W.; 16 N.E., N.W., S.W.; 17 N.E., N.W.; 22 N.E.; 37 N.W.
Middlesex.—10 N.E., S.E.; 11 S.W., S.E; 15 N.E., S.E., S.W.; 16. N.E., N.W., SW.
Shropshire.—3 S.E., S.W.; 9 N.E., N.W.
Staffordshire.—8 S.W.; 10 S.E.; 11 N.E., S.E., N.W., S.W.; 12 N.E., N.W., S.W.; 13 S.W.; 16 N.E., S.E.; 17 N.E., S.E., N.W., S.W.; 18 N.E., S.E., N.W., S.W.; 22 N.E.,* S.E.,* N.W., S.W.*
Wiltshire.—67, 74, 75.

* Revised editions.

2.—*Scotland.*

Two sheets of the one-inch map of Scotland have been published during the past year, viz.:—

46, embracing part of south-west Perthshire, extending from Loch Voil on the S.E. to Loch Tulla in the N.W., and the valleys of the Fillan, Dochart, and Lochay.

86, including parts of Aberdeenshire and Banffshire, extending from Grange east to Fyvie, and south to Huntly, and embracing a large part of the valley of the Deveron.

The following sheets of the one-inch map are in preparation.

27, containing the north part of Islay.

37, including the district on both sides of the upper part of Loch Fyne.

38, containing parts of Argyllshire, Dumbartonshire, Perthshire, and Stirlingshire.

55, showing part of Perthshire, including Blair Athole and Dalnaspidal.

15, new edition, embracing part of the Southern Uplands to the N.E. and S.W. of Sanquhar.

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Manuscript copies of the following six-inch maps have been made and deposited in the office for public reference

Caithness, 11–17.
Skye, 38.

3.—*Ireland.*

It was found necessary to delay the issue of the revised editions of Sheets 37 and 38 until the igneous rocks had been re-examined as stated on p. 5. The revision has been completed, and these sheets are now published. Most of the other sheets of the Silurian districts which have been revised to the north of Dublin are now being prepared for engraving, and will be issued, it is expected, in the course of the present year.

The following duplicate copies of six-inch maps have been made, and are deposited in the office for reference by the public :—

County Antrim.—Parts of Sheets 4, 5, and 9.
„ Down.—Parts of Sheets 45, 46, 50, 51.
„ Mayo.—Sheets 82, 93, 114, and parts of Sheets 61, 65, 66, 67, 68, 74, 81, 92, 93, 105, 106, 115.
„ Tyrone.—Part of Sheet 15.
„ Wicklow.—Sheets 15, 22, and 29.

II.—MEMOIRS.

A.—OFFICIAL.

1.—*England and Wales.*

During the past year the following six Memoirs have been published :—

"Summary of Progress of the Geological Survey of the United Kingdom for 1898," pp. vi., 216. Price 1s.

"The Geology of Belford, Holy Island, and the Farne Islands, Northumberland." (Explanation of Quarter-sheet 110 S.E., Old Series ; 4 New Series.) By WILLIAM GUNN, pp. iv., 155. Price .

"The Geology of the Country around Carlisle." (Explanation of Sheet 107, Old Series ; 16 and 17 New Series.) By T. V. HOLMES, pp. iv., 64. Price 1s. 3d.

"The Water-supply of Sussex from Underground Sources." By W. WHITAKER and CLEMENT REID., pp. iv., 123. Price 3s.

"The Geology of the Country around Dorchester." By CLEMENT REID., pp. iv., 52. Price 1s.

"The Geology of the South Wales Coal-field." Part I., The country around Newport, Monmouthshire. By AUBREY STRAHAN, pp. vi., 97. Price 2s.

The following Memoirs are in different stages of progress :—

"The Cretaceous Rocks of Britain," vol. i. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE. (*In the Press.*)

"The Geology of the Isle of Man." By G. W. LAMPLUGH. (*Partly in type.*)

"The Geology of the country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS. (*Nearly ready for the printer.*)

"Guide to the Geology of London." By W. WHITAKER. 6th edition. (*In preparation.*)

"The Geology of the country around Kingsbridge and Salcombe. By W. A. E. USSHER. (*Nearly ready for the printer.*)

"The Cretaceous Rocks of Britain," vol. ii. Chalk of England. By A. J. JUKES-BROWNE. (*MS. nearly ready for the printer.*)

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"The Geology of the country around Reading." By J. H. BLAKE. (*In preparation.*)
"The Water Supply of Berkshire." By J. H. BLAKE, with contributions by W. WHITAKER. (*Nearly ready for printer.*)
"The Geology of the South Wales Coal-field":—
Part 2. The country around Abergavenny. By A. STRAHAN, J. R. DAKYNS and W. GIBSON. (*Nearly ready.*)
Part 3. The country around Cardiff. By A. STRAHAN and T. C. CANTRILL. (*In preparation.*)
Part 4. The country around Pontypridd. By A. STRAHAN, R. H. TIDDEMAN and W. GIBSON. (*In preparation.*)

2.—*Scotland.*

The large Memoir on the Silurian Rocks of Scotland referred to in previous *Annual Reports* was published last summer. It forms an octavo volume of 749 pages, with twenty-seven plates and 121 figures in the Text; also a coloured map and sections. It forms the first of the series of Stratigraphical Monographs, which has been entirely devoted to the geology of Scotland.

Another not less important contribution to the geology of the country is that on the North-West Highlands, to which allusion was made in the last *Annual Report*. As the literary work can only be undertaken during the season when field work has to be abandoned, the progress of so voluminous a Memoir as this must be necessarily slow. But so much of it has now been completed that the MS., it is confidently hoped, will be ready to be sent to the printer before the autumn of this year.

In connection with the preparation of the Memoir on the North-West Highlands it may be added that MR. ROBERT LUNN, of the Edinburgh Office, has, during the past season, visited the ground, and has taken fifty photographs of rock-sections and of escarpments of Torridon Sandstone, a selection from which will be used as illustrations of the Memoir. While in the north he also took thirty photographs of sections of Jurassic rocks in the district of Brora, Sutherlandshire, for the illustration of these rocks in a Survey Memoir.

No explanatory Memoir of Sheet 40 (Fife and Kinross) having hitherto been prepared, and no member of the staff being available for this duty, the Director-General undertook the work himself, and before the end of the year completed it. The MS. is only waiting for the completion of the Appendix of Fossils, and it will be sent to the printer as soon as that can be prepared. Another Memoir explanatory of Sheet 41 (Eastern Fife) will be taken in hand by the Director-General during the spring. Other Memoirs are in progress, including one on Cantyre by MESSRS. SYMES and HILL, and one on Islay by MR. WILKINSON.

III.—SECTIONS.

Three Sheets of Vertical Sections to further illustrate the South Wales Coalfield had been arranged during the early part of the year by MR. STRAHAN, and they were drawn to scale by MR. GILBERT WILLIAMS. Unfortunately, when the

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work was almost completed by the lithographers, the building in which the stones and the original drawings were placed, was destroyed by fire, and no portion of the work was preserved. Steps have been taken to re-draw the sections and to issue them at as early a date as may be practicable.

B.—Non-Official.

The following is a list of the non-official publications of the members of the staff during the year 1899:—

Clough, C. T., and Alfred Harker.—"On a Coarsely Spherulitic ('Variolitic') Basalt in Skye." Trans. Edin. Geol. Soc., vol. vii., pp. 381-389.

Clough, C. T., and Dr. W. Pollard.—"On Spinel and Forsterite from the Glenelg Limestone (Inverness-shire)." Quart. Journ. Geol. Soc., vol. lv., pp. 372-380.

Geikie, Sir A.—Hutton's "Theory of the Earth, with Proofs and Illustrations." Vol. iii. Edited by Sir A. Geikie. 8vo, London.

Geikie, Sir A.—"Presidential Address. Section C., Geology, British Association. Dover, 1899." Rep. Brit. Assoc. for 1899 (1900), pp. 718–730.

Gibson, W.—"Some Recent Work among the Upper Carboniferous Rocks of North Staffordshire and its Bearing on Concealed Coalfields." Rep. Brit. Assoc. for 1899 (1900), pp. 738, 739. Geol. Mag., Dec. iv., vol. vi., pp. 505, 506.

Gibson, W., and Dr. Wheelton Hind.—"On the Agglomerates and Tuffs in the Carboniferous Limestone Series of Congleton Edge." With Appendix by H. H. Arnold-Bemrose. Quart. Journ. Geol. Soc., vol. lv., pp. 548-559.

Goodchild, J. G.—"The Bedshiel Kaims." Proc. Berwick Nats. Field Club, pp. 295–312.

Goodchild, J. G.—"On the Genesis of some Scottish Minerals." Proc. Roy. Phys. Soc. Edin., vol xiv., pp. 181–220.

Goodchild, J. G.—"Guide to the collection of Scottish Agates." Edin. Mus. Science and Art, 1899.

Gunn, W.—"Notes on the rocks about Berwick-upon-Tweed." Proc. Berwick Nat. Field Club, vol. xvi., p. 313.

Harker, Alfred.—"Chemical Notes on Lake District Rocks." *Naturalist*, pp. 53–58, 149–154.

Harker, Alfred.—"Glaciated Valleys in the Cuillins, Skye." Geol. Mag., Dec. iv., vol. vi., pp. 196–199.

Harker, Alfred.—"On the Average Composition of British Igneous Rocks." Ibid., pp. 220–222.

Harker, Alfred.—"Notes on Subaerial Erosion in the Isle of Skye." Ibid., pp. 485–491.

Hill, J. B.—"On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe." Quart. Journ. Geol. Soc., vol. lv., pp. 470–493.

Hill, J. B.—"The Lower Palæozoic Rocks of the South of Scotland, viewed in connection with the Lower Palæozoic Rocks of Cornwall." Trans. Roy. Geol. Soc., Cornwall.

Jukes-Browne, A. J.—"The Submerged Platform of Western Europe." Geol. Mag., Dec. iv., vol. vi., pp. 94–96.

Jukes-Browne, A. J.—"Zones and 'Chronological' Maps." Ibid. pp. 216–219.

Jukes-Browne, A. J.—"The Association of *Schlœnbachia inflata* with *Hoplites interruptus*." Ibid., pp. 234, 235.

Kynaston, H.—"Contributions to the Petrology of the Cheviot Hills." Trans. Edin. Geol. Soc., vol. vii., p. 390.

Newton, E. T.—"On Remains of Amia from Oligocene Strata in the Isle of Wight." Quart. Journ. Geol. Soc., vol. lv., pp. 1–10.

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NEWTON, E. T.—"On a Megalosauroid Jaw from Rhaetic beds near Bridgend (Glamorganshire)." Quart. Journ. Geol. Sc., vol. lv., pp 89–96.

NEWTON, E. T.—"Additional Notes on the Vertebrate Fauna of the Rock Fissure at Ightham (Kent)." Ibid., pp. 419–429.

NEWTON, E. T.—"Remarks on *Mus Abbotti*." Proc. Zool. Soc., 1899 p. 318.

NEWTON, E. T.—"Note on the Mammalian Remains found at Carshalton." Trans. Croydon Micros. Nat. Hist. Club, 1899, p. 292.

NEWTON, E. T.—"Report upon series of Bones obtained by Sir Thos. Wardle from a Cave at Red Hurst, near Wetton, Leek." See Account of the researches at this Cave by Sir Thos. Wardle The *Leek Post*, Sat. Feb. 25th, 1899.

NEWTON, E. T.—"Notes on the Fossils collected by Colonel H. W. Feilden in Novaya Zemlya, 1897." "Beyond Petsora Eastward," by Henry J. Pearson, 8vo, London, 1899, p. 287 ; see also pp. 236, 242.

NEWTON, E. T.—"Notes on Fossils of Carboniferous Age, collected by Mr. Wm. S. Bruce, at Cape Cherni, Novaya Zemlya, in 1898." "Beyond Petsora Eastwards," p. 294.

NEWTON, E. T.—"On the Osteological specimens collected at Skitts Hill, near Braintree." See paper on "A supposed Neolithic Settlement at Skitts Hill, near Braintree," by Rev. J. W. Kenworthy, *Essex Naturalist*, vol. xi., p. 94.

PEACH, B. N.—"On some New Myriopods from the Palæozoic Rocks of Scotland." Proc. Roy. Phys. Soc. Edin. vol. xiv., p. 113.

REID, C.—"The Origin of the British Flora." 8vo, London, pp. vi, 191.

STRAHAN, A.—"The Age of the Vale of Clwyd." Geol. Mag., Dec. iv., vol. vi., pp. 111–117.

TEALL, J. J. H.—"The Natural History of Cordierite and its Associates. Presidential Address to Geologists' Association." Proc. Geol. Assoc., vol. xvi., pp. 61–74.

WEDD, C. B.—"Note on Barium Sulphate in the Bunter Sandstone of North Staffordshire." Rep. Brit. Assoc. for 1899 (1900), p. 740 ; Geol. Mag., Dec. iv., vol. vi , p. 508.

WOODWARD, H. B., and W. A. E. USSHER.—"Excursion to Seaton, Sidmouth, Budleigh Salterton, and Exeter." Proc. Geol. Assoc., vol. xvi., pp 133-153.

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APPENDIX.

CATALOGUE of TYPES and FIGURED SPECIMENS from the EOCENE and OLIGOCENE SERIES preserved in the Museum of Practical Geology.

By H. A. ALLEN, F.G.S.

N.B.—The letter **T** *indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain; these are marked* **[Doubtful]**.

EOCENE.

PLANTÆ.

Alnites ? MacQuarrii, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 3, p. 103.
Eocene. Ardtun, Mull.

Andromeda reticulata, Ett.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxviii., figs. 10, 11, p. 1067.
Bagshot Series. Bovey Tracey, Devon.

Anona cyclosperma, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., f. 4, p. 1072.
Bagshot Series. Bovey Tracey.

Anona ? devonica, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 1, 2, 3, p. 1071.
Bagshot Series. Bovey Tracey.

Apeiobopsis Symondsii, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 5, p. 116.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.

Aralia primigenia, De la Harpe.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 4, p. 117.
Lower Bagshot Series. Alum Bay, Isle of Wight.

Aralia primigenia, De la Harpe. **T.**
De la Harpe, Mem Geol. Survey, Isle of Wight, 1862, pl. vii., f. 5, p. 117.
Lower Bagshot Series. Alum Bay.

Buds. **T.**
J. D. Hooker, Quart. Journ. Geol. Soc., vol. x., 1854, pl. iv., f. 25, p. 163.
Reading Series. Reading.

Cæsalpinia æmula, Heer.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 6, p. 118.
Lower Bagshot Series. Alum Bay.

Cæsalpinia Bowerbanki, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 10, p. 119.
Lower Bagshot Series. Alum Bay.

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Cæsalpinia ? brevis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., figs. 12, 13, p. 119.
Lower Bagshot Series. Alum Bay.

Cæsalpinia ? mollis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 14, p. 119.
Lower Bagshot Series. Alum Bay.

Cæsalpinia Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 11, p. 119.
Lower Bagshot Series. Alum Bay.

Carpolithes exaratus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 24-27, p. 1079.
Bagshot Series. Bovey Tracey.

Carpolithes lividus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 30 and 31, p. 1080.
Bagshot Series. Bovey Tracey.

Carpolithes vinaceus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152., 1863, pl. lxx., f. 28, p. 1080.
Bagshot Series. Bovey Tracey.

Carpolithes Websteri (Brongn.), Heer.
O. Heer, Phil. Trans, vol. 152, 1863, pl. lxx., fig. 6, p. 1075.
Bagshot Series. Bovey Tracey.

Cassia Ungeri, Heer.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., figs. 7, 8, 8*a*, p. 118.
Lower Bagshot Series. Alum Bay.

Cinnamomum lanceolatum, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxvii., figs. 1, 2, 4 ; pl. lviii., f. 14 p. 1063.
Bagshot Series Bovey Tracey.

Cinnamomum Rossmässleri, Heer.
O. Heer, Phil. Trans, vol. 152, 1863, pl. lxvii., figs. 17, 18, p. 1062.
Bagshot Series. Bovey Tracey.

Cinnamomum Scheuchzeri Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxvii., figs. 11, 14, 16, p. 1063
Bagshot Series. Bovey Tracey.

Cyperites deperditus, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lx., f. 54, p. 1056.
Bagshot Series. Bovey Tracey.

Daphnogene Ungeri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., figs. 1, 2, p. 1064.
Bagshot Series. Bovey Tracey.

Dalbergia ? Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 9., p. 118.
Lower Bagshot Series. Alum Bay.

Dryandra acutiloba (Brongn.)
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., figs. 6 and 7, p. 115.
Lower Bagshot Series. Alum Bay.

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Dryandra Bunburyi, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 4, p. 115.
Lower Bagshot Series. Alum Bay.

Echitoneum cuspidatum, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiv., f. 5, p. 1068.
Bagshot Series. Bovey Tracey.

Elæodendron ? Heeri. De la Harpe. [Doubtful] T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 5, p. 114
Bagshot Series. Bournemouth.

Equisetum Campbellii, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., figs. 6*a*, 6*b*, p. 103.
Eocene. Ardtun, Mull

Ficus Bowerbankii, De la Harpe. T.
De la Harpe, Mem. Geo. Survey, Isle of Wight, 1862, pl. vi., figs. 1 and 2, p. 112.
Lower Bagshot Series. Alum Bay.

Ficus eucalyptoides, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., figs. 3, 4, p. 1061.
Bagshot Series. Bovey Tracey.

Ficus Falconeri, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., f. 1*a*; pl. lxiv., fig. 7, p. 1060.
Bagshot Series. Bovey Tracey.

Ficus Forbesii, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 4, p. 113.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.

Ficus granadilla (Massal.).
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 3, p. 113,
Lower Bagshot Series. Alum Bay.

Ficus Pengellii, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., f. 8, p. 1061.
Bagshot Series. Bovey Tracey.

Filicites ? hebridicus, Forbes. T.

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 2*a*, 2*b*, p. 103. Refigured as **Onoclea hebraidica**, J. S. Gardner, "Eocene Flora," Mon. Pal. Soc., 1882, pl. xiii., figs. 5, 5*a*, p. 68.
Eocene. Ardtun, Mull.

Gardenia Wetzleri, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxix., f. 1, p. 1069.
Bagshot Series. Bovey Tracey.

Goniopteris stiriaca. *Vide* **Lastræa stiriaca.**

Lastræa (Goniopteris) Bunburii, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 1 *b*, *c*, *d*, p. 1046.
Bagshot Series. Bovey Tracey.

Lastræa (Goniopteris) stiriaca, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 9, 10, 11, 14, 15, p. 1046. Refigured as **Goniopteris stiriaca**, J. S. Gardner, Mon. Pal Soc., 1880, p. 40, f. 20 (Woodcut).
Bagshot Series. Bovey Tracey

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Laurus Jovis, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 3, p. 114.
Lower Bagshot Series. Alum Bay.

Laurus primigenia. Unger.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., f. 6, p. 1062.
Bagshot Series. Bovey Tracey.

Laurus ? Salteri, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 1, p. 115.
Lower Bagshot Series. Alum Bay.

Nymphæa Doris, Heer. **T.**
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 32–37, p. 1072.
Bagshot Series. Bovey Tracey.

Onoclea hebraidica. *Vide* **Filicites ? hebridicus**.

Palmacites Dæmonorops (Unger).
O. Heer, Phil. Trans., vol. 152, 1863, pl. lv., figs. 8, 9, 10; pl. lxii., figs. 3, 6, 8, p. 1056.
Bagshot Series. Bovey Tracey.

Pecopteris (Hemitelia ?) lignitum, Giebel.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 3, 5, 7, 8, 9, 10; pl. lvii., f. 1, p. 1047.
Bagshot Series. Bovey Tracey.

Platanites hebridicus, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 1, p. 103.
Eocene. Ardtun, Mull.

Platanites hebridicus, var. ? Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 5, p. 103.
Eocene. Ardtun, Mull.

Pteris eocænica, Ett. and Gard. **T.**
Gardner and Ettingshausen, "Eocene Flora." Mon. Pal. Soc., 1882, pl. xii., f. 11, 11*a*, pp. 32 and 62.
Bagshot Series. Bournemouth.

Pterocarya denticulata ? Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., fig. 5, p. 1074.
Bagshot Series. Bovey Tracey.

Quercus eocenica, De la Harpe. **T.**
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 2, p. 112.
Lower Bagshot Series. Alum Bay.

Quercus Lyelli, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 3, 5, 6, 7, 8; pl. lxviii., figs. 4, 6, p. 1058.
Bagshot Series. Bovey Tracey

Rhamnites ? multinervatus, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 2, p. 103.
Eocene. Ardtun, Mull.

Rhamnites ? major, Forbes. **T.**
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 3, p. 103.
Eocene. Ardtun, Mull.

Sequoia Couttsiæ, Heer.
J. S. Gardner, Mon. Pal. Soc., 1883, pl. vi., figs. 14–17, pp. 36 and 90.
Middle Bagshot Series. Bovey Tracey.

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Sequoia Langsdorfii. *Vide* **Taxites ? Campbellii.**

Taxites ? Campbellii, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 1*a*, 1*b* p. 103. Refigured as **Taxus Campbelli,** J. S. Gardner, "Eocene, Flora," Mon. Pal. Soc., 1885, pl. x., figs. 1, 1*a*, p. 101.
Eocene. Ardtun, Mull.

Taxus Campbelli. *Vide* **Taxites ? Campbellii.**
"Affinities doubtful."
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., pl. iv., f. 2, p. 103.
Eocene. Ardtun, Mull.

ANIMALIA.

Protozoa.

Nummulites elegans, J. C. Sow.
Rupert Jones, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. xi., f. 1, p. 142.
Barton Series. Whitecliff Bay, I.W.

Echinodermata.

Astropecten ? Colei, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 3 *a*, *b*, p. 30.
London Clay. Sheppey.

Astropecten crispatus, Forbes. T.
Ansted, "Geology," vol. ii., 1844, p. 66 (Woodcut).
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 479.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 2 *a*, *b*, p. 29.
London Clay. Sheppey.

Astropecten crispatus, Forbes.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. iii., figs. 3 *b*, *c*.
London Clay. Sheppey.

Cainocrinus tintinnabulum, Forbes. T.
E. Forbes, Mon. Pal. Soc. 1852, p. 33 (Woodcut).
London Clay. Hornsey.

Cidaris websteriana, Forbes. T
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 4, p. 22.
Barton Series. Barton, Hants.

Cœlopleurus Wetherelli, Forbes T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 1 *a*, *b*, *c*, p. 24.
London Clay. Sheppey.

Echinopsis Edwardsi, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 2, p. 23.
Bracklesham Series. Bracklesham.

Echinus dixonianus, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 3, p. 22.
Barton Series. Barton, Hants.

Eupatagus Hastingiæ, Forbes. T.
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 7, p. 26.
Barton Series. Barton, Hants.

Goniaster (Astrogonium) marginatus, Forbes. T.
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, f. 2.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 4, p. 31
London Clay. Sheppey.

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Goniaster (Astrogonium) Stokesii, Forbes. **T.**
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, figs. 1 *a*, *c*, *d*.
London Clay. Sheppey

Goniaster tuberculatus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 5, p. 31.
London Clay. Sheppey

Hemiaster Bowerbanki, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 6, p. 24.
London Clay. Sheppey.

Hemiaster branderianus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *a*, *b* *c*, p. 25.
Barton Series. Barton, Hants.

Hemiaster branderianus, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *d*, *e*, p. 25.
London Clay. Haverstock Hill.

Hemiaster? Prestwichii, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 5 *a*, *b*, *c*, p. 25.
London Clay. Sheppey.

Ophiura Wetherelli, Forbes. **T.**
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 7*b*, p. 32.
London Clay. Highgate.

Pentacrinus subbasaltiformis, Miller.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 9, 10, p. 34.
London Clay. Hornsey.

Spatangus Omalii, Galeotti.
E. Forbes, Mon. Pal. Soc, 1852, pl. iii., figs. 9 *a*, *c*, p. 28.
Barton Series. Barton, Hants.

LAMELLIBRANCHIATA.

Cytherea incurvata, Edw. **[Doubtful.]**
Lowry's Chart of the British Tertiary Fossils, 1866.
Bracklesham Series.

Modiola? tubicola, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1859, pl. xiii., f. 12, p. 73.
London Clay. Whetstone?

Nucula proava, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., figs. 3 *a*, *b*, p. 117.
London Clay (Basement Bed). Near Bishopstone, Herne Bay.

Nucula striatella, S. V. Wood. **T.**
S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., fig. 9, p. 123.
London Clay (Basement Bed). Herne Bay.

Ostrea tabulata, J. C. Sow.
S. V. Wood, Mon. Pal. Soc., 1861, pl. iv. f. 1*b*, p. 31.
Bracklesham? Bognor.

Perna croydonensis, Newton. **T.**
E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, p. 249.
Woolwich and Reading Series. Park Hill, Croydon.

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Vulsella deperdita? Lam.
S. V. Wood, Mon. Pal. Soc., 1861, pl. ix., f. 2*c*, p. 35.
Barton Series. Barton, Hants.

GASTEROPODA.

Camptoceras priscum, Austin. T.
H. H. Godwin-Austen, Quart. Journ. Geol. Soc., vol. xxxviii., 1882, pl. v., figs. 1-5, p. 220.
London Clay. Between East End Lane and Hensbrook, Sheppey.

Fusus nitidus, Price. T.
F. G. H. Price, Proc. Geol. Assoc., vol. iii., 1874, pl. ii., fig. 2.
London Clay. Law Courts Area, Strand, London.

Pleurotoma varicosa, Price. T.
F. G. H. Price, Proc. Geol Assoc., vol. iii., 1874, pl. ii., fig. 1.
London Clay. Law Courts Area, Strand, London.

VERTEBRATA.

Arius crassus, (Koken) Newton. T.
E. T. Newton, Proc. Zool. Soc., 1889, pl. xxi., figs. 1-3, p. 206.
Barton Series. Barton, Hants.

Notidanus serratissimus, Ag.
A. S. Woodward, Proc. Geol. Assoc., vol. xvi., 1899, pl. 1, f. 7, p. 6.
London Clay. Sheppey.

Emys delabechei, T. Bell. T.
T. Bell in R. Owen, Mon. Pal. Soc., 1849, pl. xxviii., p. 74.
London Clay. Sheppey.

Agnopterus? hantoniensis. Lyd. T.
R. Lydekker, Cat. Foss. Birds in Brit. Museum, p. 97.
Middle Eocene. Hordwell.

Gastornis Klaasseni, Newton. T.
E. T. Newton, Trans. Zool. Soc., vol. xii., 1886, pl. xxviii., xxix., p. 143.
Lower Eocene. Park Hill, Croydon.

Proherodius Oweni, Lyd. T.
R. Lydekker, Cat. Foss. Birds in Brit. Museum, fig. 75, p. 364.
London Clay. Admiralty Building, St. James's Park.

Coryphodon croydonensis, Newton. T.
E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, pl. iii., p. 250.
Lower Eocene. Park Hill, Croydon.

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OLIGOCENE.

PLANTÆ

Andromeda reticulata, Ett.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., f. 13, p. 373.
Hamstead Series. Hamstead, I.W.

Chara Lyellii (Forbes MS.), Salter. **T.**
J. W Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii., f. 10, p. 160.
Bembridge Series. St. Helens, I.W.

Chara tuberculata, Lyell, var. **Morrisii**, Salter. **T.**
J. W. Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii., f. 14, p. 159.
Hamstead Series. Hamstead, I.W.

Cyperites Forbesii, Heer. **[Doubtful] T.**
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 20, 21, p. 373.
Hamstead Series. Hamstead, I.W.

Limnocarpus headonensis (Gardner). Type of the genus. **T.**
Clement Reid, Journ. Linn. Soc., vol. xxxiii., 1898, p. 465 (woodcut).
Lower Headon Series. Hordle Cliff, Hampshire.

Nelumbium Buchii, Ett.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 19 *c*, *d*, *e*, p. 374.
Hamstead Series. Hamstead, I.W.

Sabal major, Unger.
J. S. Gardner, Rep. Brit. Assoc. for 1887, pl. v., f. 5, p. 423.
Bembridge Series. Hamstead, I.W

Sequoia Couttsiæ, Heer.
O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs 1–7, p. 372. Refigured as **Athrotaxis Couttsiæ**, J. S. Gardner, "Eocene Flora," Mon. Pal. Soc., 1884, pl. vi., figs. 3 and 8, pp. 36 and 90.
Hamstead Series. Hamstead, I.W.

CŒLENTERATA.

Madrepora anglica, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 1–7, p. 51.
Middle Headon Series Brockenhurst.

Madrepora Roemeri, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 8, 10, 11, p. 51.
Middle Headon Series. Brockenhurst.

Solenastræa cellulosa, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., f. 7, p. 41.
Middle Headon Series. Brockenhurst.

Solenastræa granulata, Dunc.
P. M. Duncan, Mon. Pal. Soc., 1866, pl. vi., f. 14, p. 45.
Middle Headon Series Brockenhurst.

Solenastræa Koeneni, Dunc. **T.**
P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., figs. 8, 9, p. 42.
Middle Headon Series. Brockenhurst.

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BRYOZOA.

Membranipora Buski, Gregory. T.
J. W. Gregory, Trans. Zool. Soc., vol. xiii., 1895, pl xxix., f. 12, p. 229.
Headon Series. Colwell Bay, I.W.

LAMELLIBRANCHIATA.

Arca Websteri (Forbes MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 8, p. 150.
Bembridge Series. Isle of Wight.

Corbula pisum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 1, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Corbula vectensis (Forbes MS.), Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 2, pp. 46 and 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cyclas Bristovii (Forbes MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 3, p. 146.
Hamstead Series. Hamstead Cliff, I.W.

Cyrena deperdita, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 11, 11 *a*, *b*, p. 156.
Headon Series. Isle of Wight.

Cyrena gibbosula, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 13, 13 *a*, *b*, p. 156.
S. V. Wood, Mon. Pal. Soc., Supp. 1877, pl. B, figs. 6 *a*, *b*, p. 14.
Headon Series. Colwell Bay.

Cyrena obtusa (Forbes MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., figs. 4, 4 *a*, *b*, p. 149.
Bembridge Series. Hamstead Cliff, I.W.

Cyrena pulchra, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 1, p. 148.
Bembridge Series (Green Marls). Isle of Wight.

Cyrena semistriata, Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 2, p. 148.
Bembridge Series. Isle of Wight.

Cyrena semistriata, Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 2, p. 146.
Hamstead Series (Corbula Beds). Hamstead, I.W.

Cyrena semistriata, Desh., var.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 3, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

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Cyrena transversa (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii. f. 6, p. 149.
Bembridge Series. Hamstead Cliff, I.W

Cyrena Wrightii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., figs. 11, 11 *a*, *b*, p. 153.
Headon Series. Isle of Wight.

Cytherea incrassata, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 10, p. 153.
Headon Series. Colwell Bay.

Cytherea incrassata (cast of), J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 10, p 150.
Bembridge Series. Isle of Wight.

Cytherea (Venus) Lyellii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 4, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W..

Modiola Prestwichii, Morris. (**M. nystiana**, Forbes, on plate.) **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 5, pp. 46 and 147.
Hamstead Series. Hamstead Cliff, I.W.

Mya (Panopæa) minor (Forbes MS.), Morris, 1856. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 3, p. 149.
Bembridge Series. Isle of Wight.

Mya (Panopæa) minor, var. (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 4, p. 146.
Hamstead Series. Hamstead, I. W.

Nucula headonensis (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 12, 12 *a*, *b*, p. 156.
Middle Headon Series. Colwell Bay.

Nucula similis, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 5, p. 149.
Bembridge Marls. Isle of Wight.

Ostrea callifera, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., figs. 5, 5*a*, p. 145.
S. V. Wood, Mon. Pal. Soc., 1861, pl. v., f. 1*a*, p. 18.
Hamstead Series (Upper Beds). Hamstead, I.W.

Ostrea vectensis (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., figs. 9, 9*a*, 9*b*, p. 150.
S. V. Wood, Mon. Pal. Soc., 1861, pl. vii., figs. 5*a*, 5*b*, p. 32.
Bembridge Series. Isle of Wight.

Unio Austenii (Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 7, p. 147.
S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 12, p. 133.
Hamstead Series. Hamstead, I. W.

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Unio Gibbsii (Forbes MS.), Morris.
S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 14, p. 133.
Hamstead Series. Isle of Wight.

Unio Gibbsii (Forbes MS.), Morris. [Doubtful]. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 6, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

GASTEROPODA.

Ancillaria subulata, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 1, 1*a*, p. 155.
Headon Series. Hordwell.

Borsonia sulcata (Edwards MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., figs. 3, 3*a*, 3*b*, p. 154.
Headon Series. Colwell Bay.

Cerithium Austeni, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 11, p. 150.
Bembridge Series. Hamstead Point, I.W.

Cerithium concavum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 9, p. 153.
Headon Series. Isle of Wight.

Cerithium elegans, Desh. [Doubtful]
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 10, p. 147.
Bembridge Series. Headon, I.W

Cerithium inornatum, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 13, p. 148.
Hamstead Series. Hamstead, I.W.

Cerithium margaritaceum, J. Sow. var. Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isles of Wight, 1856, pl. iii., f. 13, p. 150.
Bembridge Series. Hamstead, I.W.

Cerithium mutabile, Lam. var. ? Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 12, p. 150.
Bembridge Series. Isle of Wight.

Cerithium mutabile, Lam. var. ? Desh.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 6, p. 152.
Headon Series. Isle of Wight.

Cerithium plicatum, Brug.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 7, p. 146.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cerithium plicatum, Brug.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 11, p. 147.
Hamstead Series (Upper Beds). Hamstead, I.W.

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Cerithium pseudocinctum, d'Orb. [Doubtful]
Morris in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 7, p. 153.
Headon Series. Colwell Bay.

Cerithium Sedgwicki, Morris. [Doubtful] T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 12, p. 147.
Hamstead Series. Hamstead, I.W.

Cerithium trizonatum, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 8, p. 153.
Headon Series. Isle of Wight.

Cerithium ventricosum, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 2, p. 152.
Headon Series. Isle of Wight.

Fusus Edwardsii, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 15, p. 148.
Hamstead Series (Upper Beds). Hamstead, I.W.

Melania Forbesii, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 15, p. 151.
Bembridge Series. Hamstead, I.W.

Melania inflata, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 8, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

Melania inflata, Morris, var. **lævis**, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 9, p. 147.
Hamstead Series. Hamstead Cliff, I.W.

Melania muricata (S. V. Wood MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 16, p. 151.
Bembridge Series. Isle of Wight.

Melania muricata, Wood, var. **costata** (Sow. sp.), Morris.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii. f. 14, p. 148.
Hamstead Series. Hamstead, I.W.

Melania muricata, Wood, var. **excavata**, Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 17, p. 151.
Bembridge Series. Bembridge, I.W.

Melania per-acuminata (Charlsw MS.), Morris. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 5, p. 152.
Headon. Isle of Wight.

Melania turritissima, Forbes. T.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 14, p. 150.
Probably the specimen figured in Lyell "Manual of Geology," 5th Edition, 1855, p. 209 (Woodcut).
Bembridge Series. Hamstead Cliff, I.W.

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Melanopsis brevis, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 10, p. 156.
Headon Series. Colwell Bay, I.W.

Melanopsis carinata, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 8, p. 156.
Headon Series. Headon Hill.

Melanopsis carinata, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs 9, 9*a*, p. 156.
Headon Series. Colwell Bay.

Melanopsis fusiformis, J. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 7, 7*a*, p. 156.
Headon Series. Colwell Bay.

Melanopsis subcarinata, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., f. 5, p. 156.
Headon Series. Headon Hill.

Melanopsis subcarinata, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl vi., figs. 6 and 6*a*, p. 156.
Headon Series. Headon Hill, I.W.

Melanopsis subfusiformis, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 2, 2*a*, and 3, p. 155.
Headon Series. Isle of Wight.

Melanopsis subulata, J. Sow. **[Doubtful]**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 4 and 4*a*, p. 155.
Headon Series. Headon Hill.

Natica labellata, Lam.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 6, p. 146.
Hamstead Series (Upper Beds). Hamstead, I.W.

Pleurotoma headonensis (Edw. MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 4, p. 155.
Headon Series. Colwell Bay.

Pleurotoma innexa (Sol.).
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 5, p. 154.
Headon Series. Colwell Bay.

Pleurotoma plebeia, J. C. Sow.
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., figs. 1, 1 *a*, *b*, p. 154.
Headon Series. Colwell Bay.

Pleurotoma plebeia, var. Morris (var. *b* Forbes MS.), Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., f. 2, p. 154.
Middle Headon Series. Isle of Wight.

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Rissoa (Hydrobia) Chastelii ? (Nyst). (*Hydrobia* on plate.)
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 3, pp. 148 and 152.
Headon Series. Isle of Wight.

Scalaria lævis, Morris. **T.**
J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 1, p. 151.
Headon Series. Isle of Wight.

VERTEBRATA.

Amia anglica, Newton. **T.**
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., figs. 1–5, p. 1.
Bembridge Marl. Hamstead, I.W.

Amia anglica, Newton.
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 19, p. 1.
Osborne Beds. Ryde House, Ryde, I.W.

Amia Colenutti, Newton. **T.**
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 22, p. 8.
Osborne Beds. King's Quay, I.W.

Hyopotamus sp.
W. Kowalevsky, Phil. Trans., vol. 163, 1873, pl. xxxix., fig. 7, p. 30.
Hamstead Series. Hamstead, I.W.

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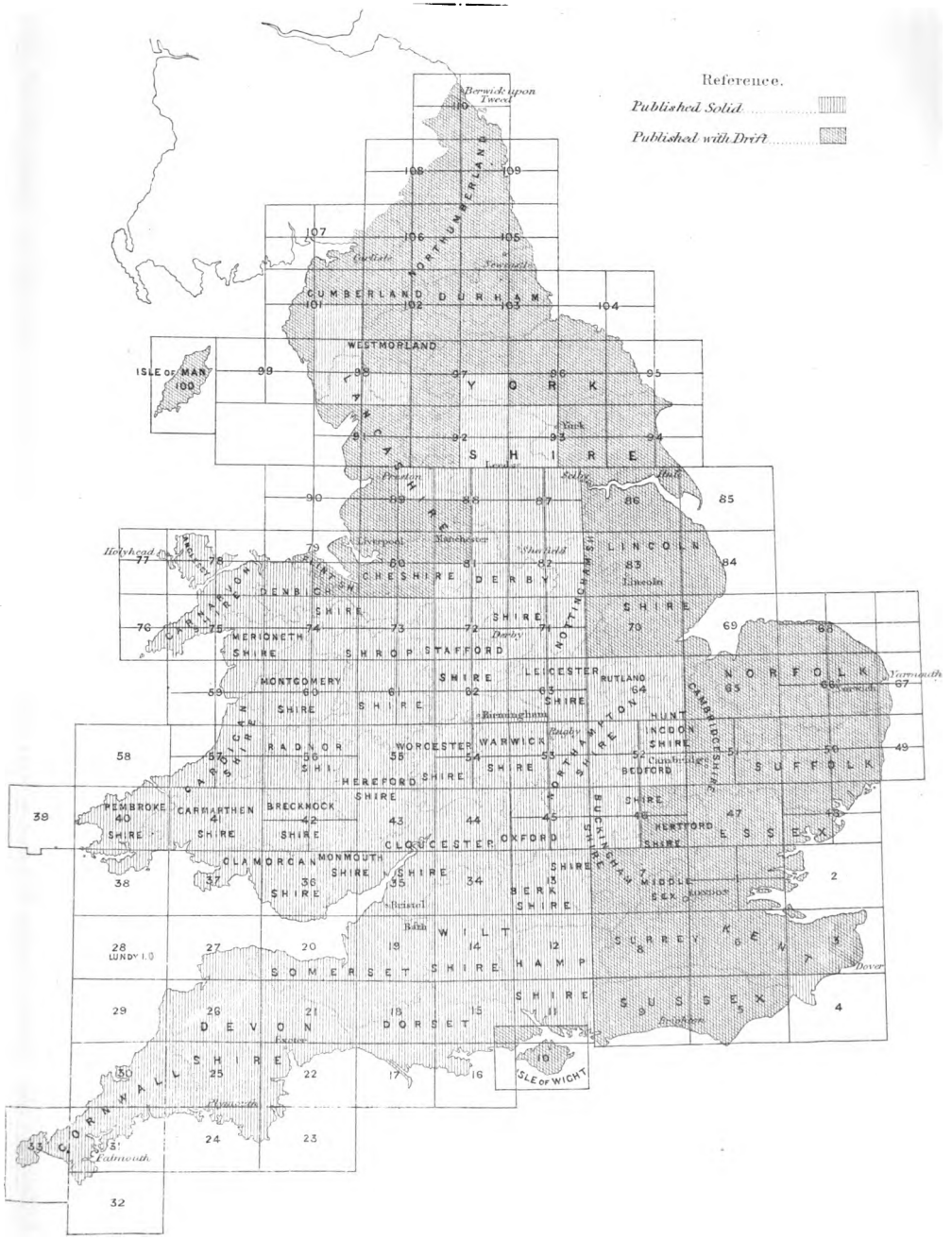

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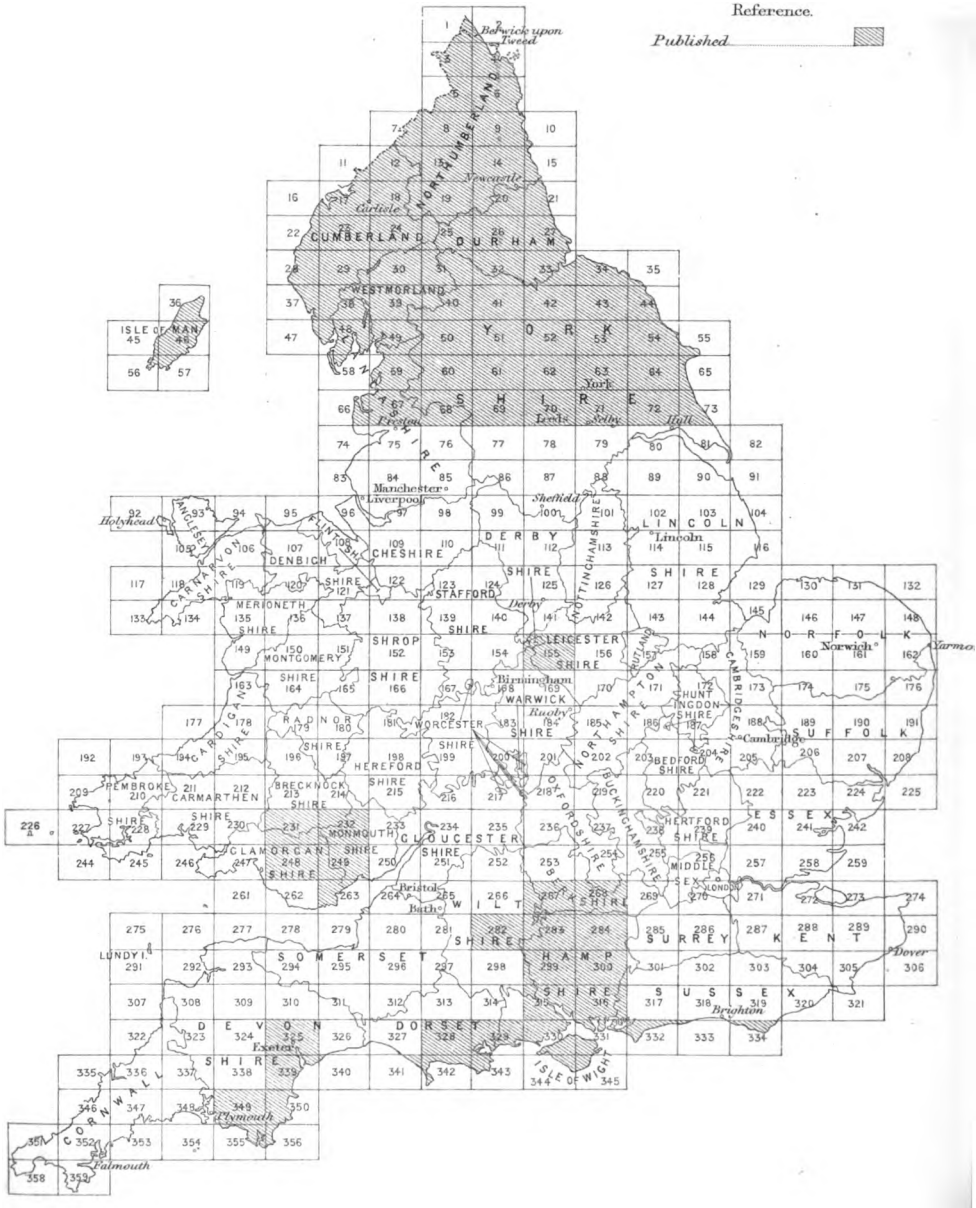

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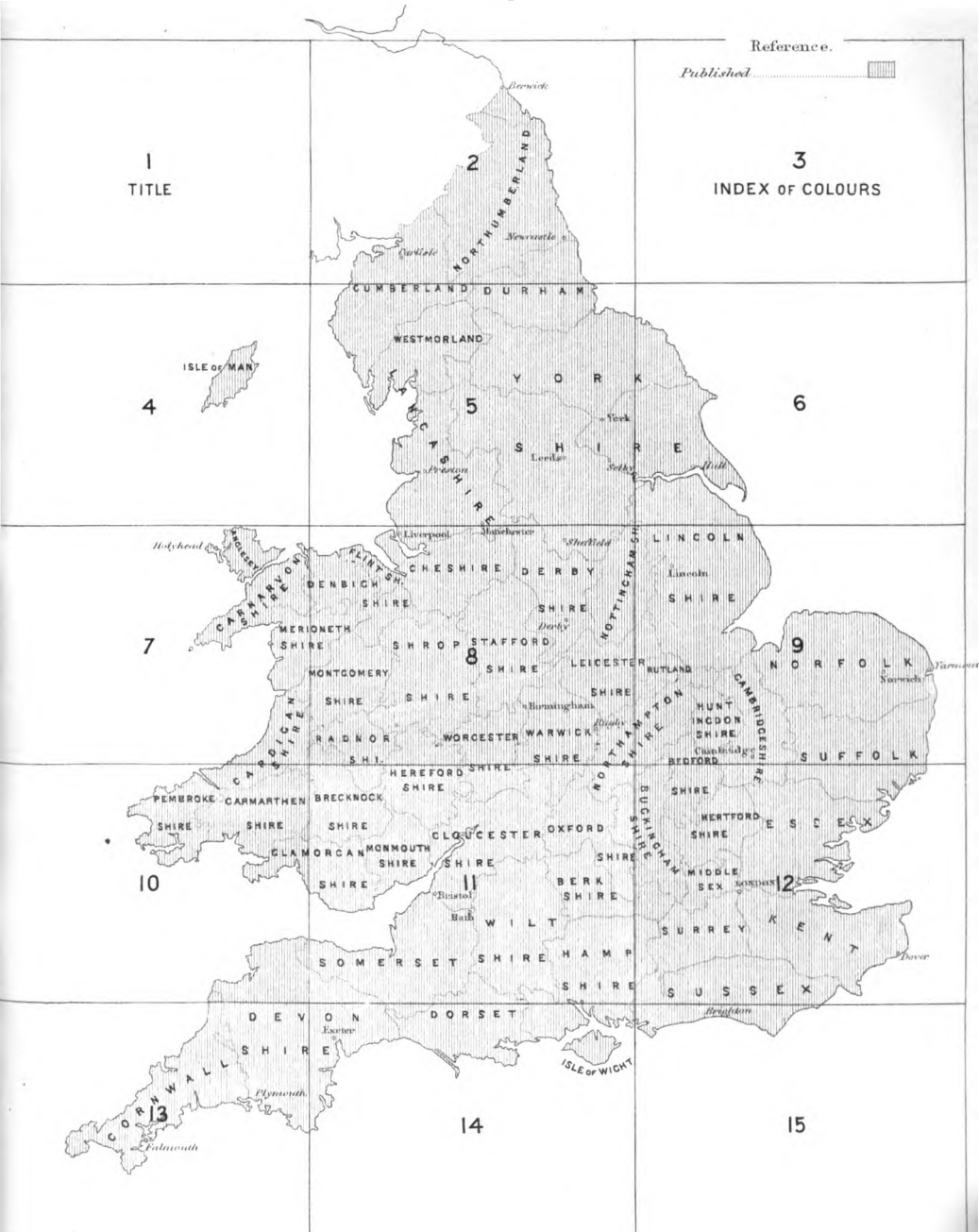

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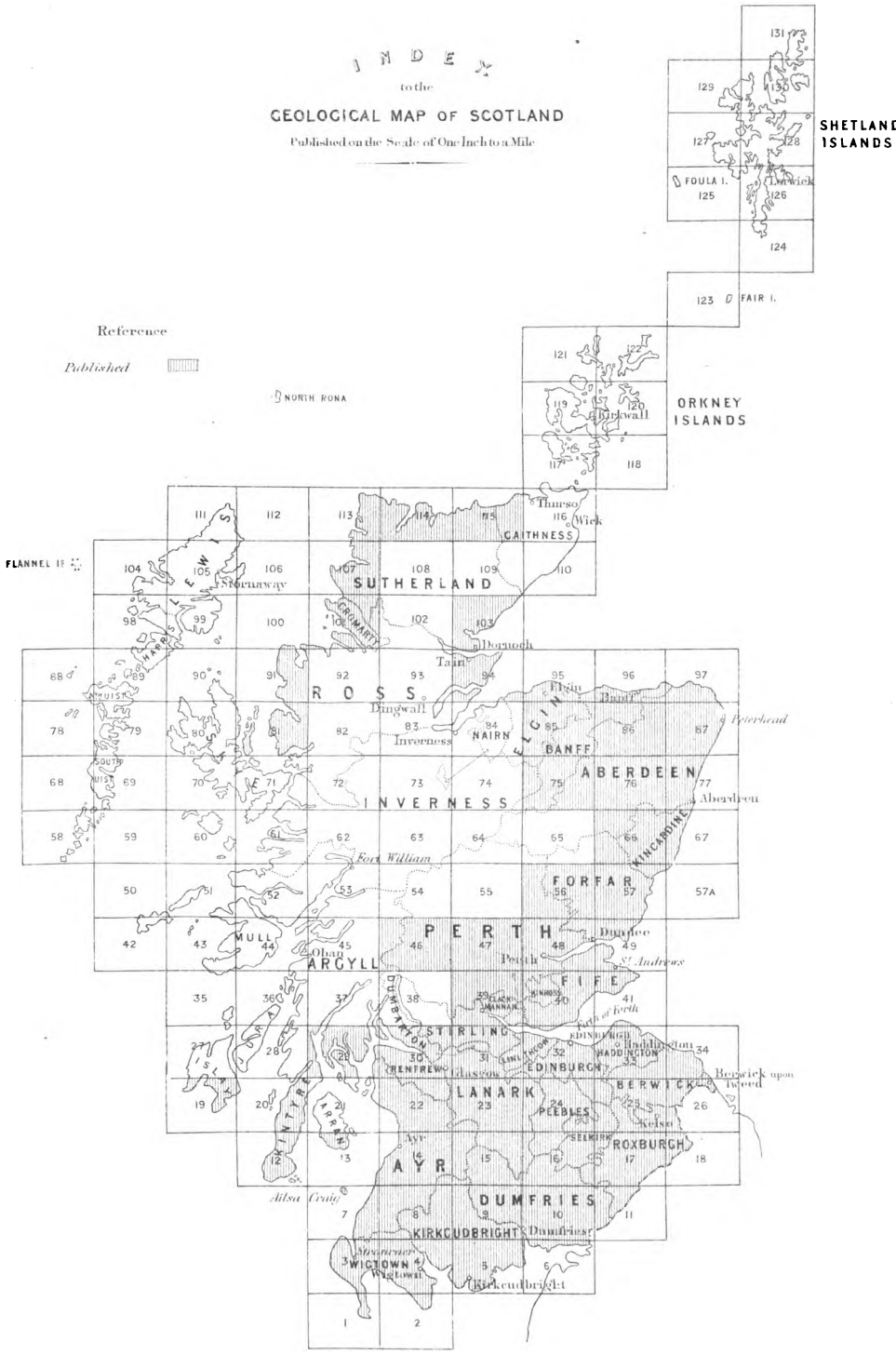

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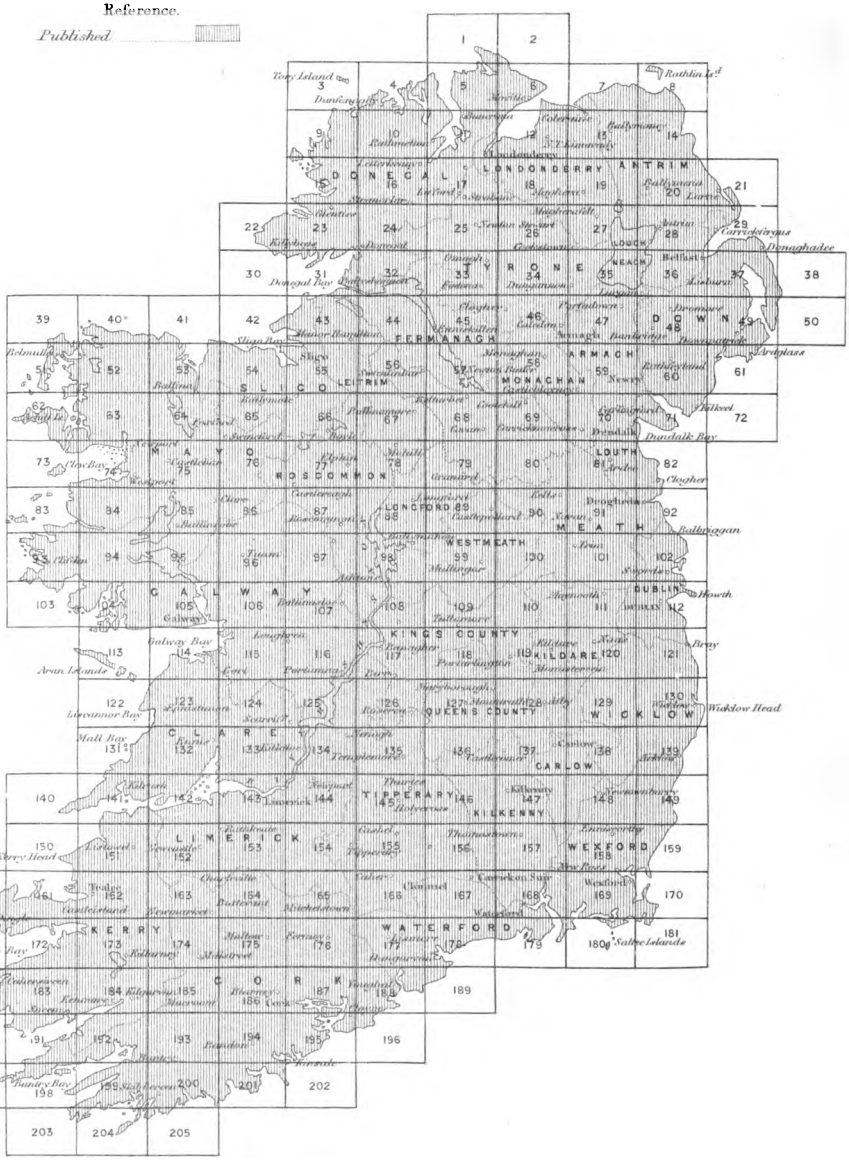

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